Status of SC RF Accelerators - World-Wide SRF Experience

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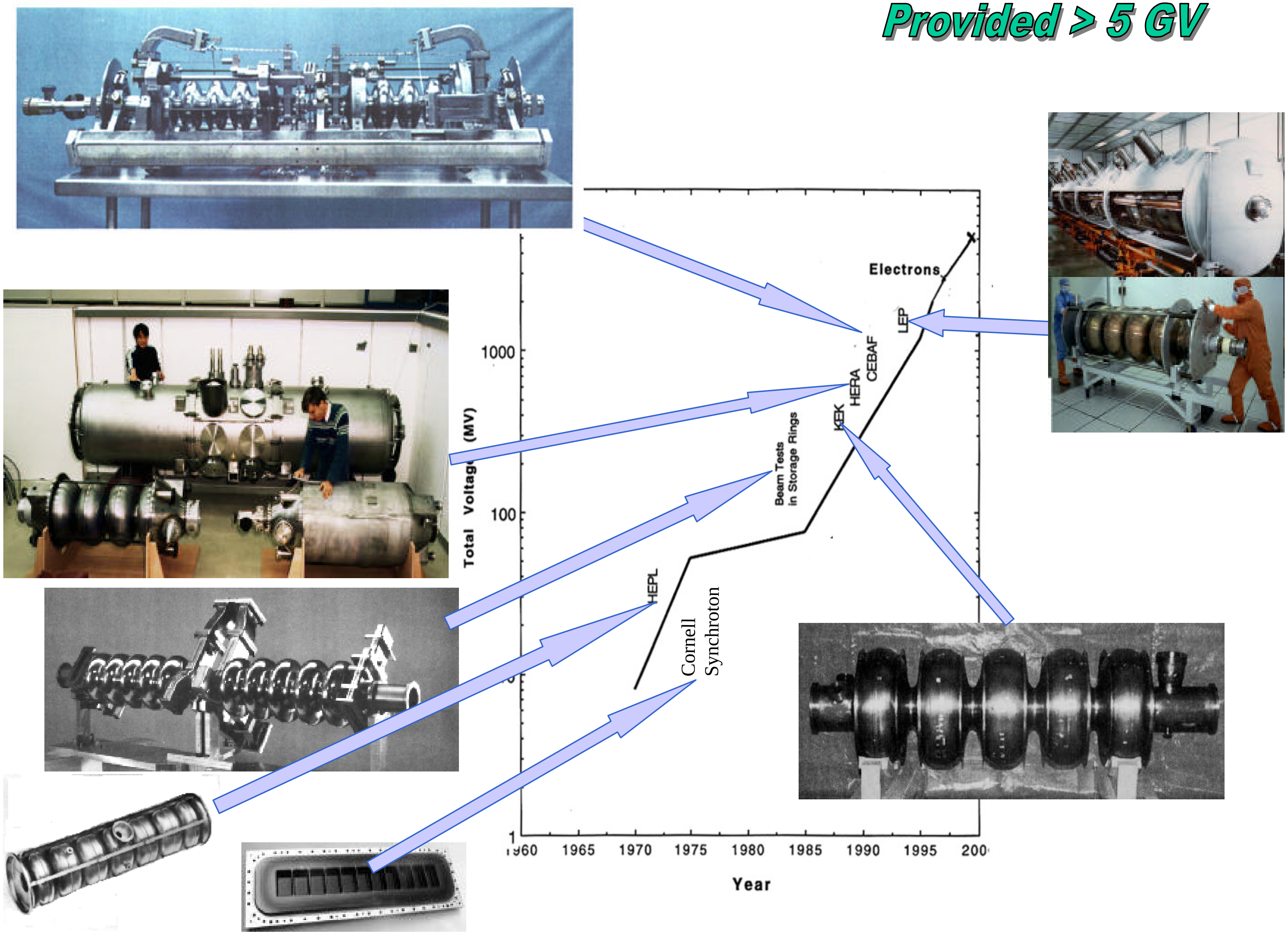
Cornell

Steady Growth Worldwide of Accelerator Applications of SC RF 1970 - 2004

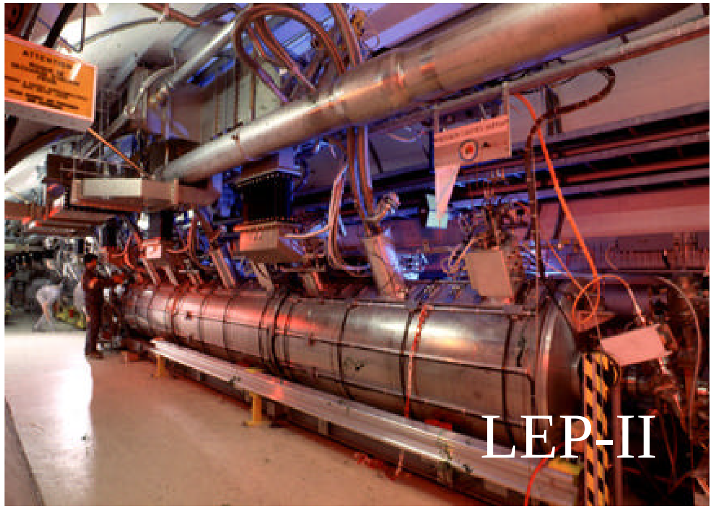
- High Energy Particle Physics
- Nuclear Physics
- Light Sources
- High Intensity Proton (Neutron) Sources

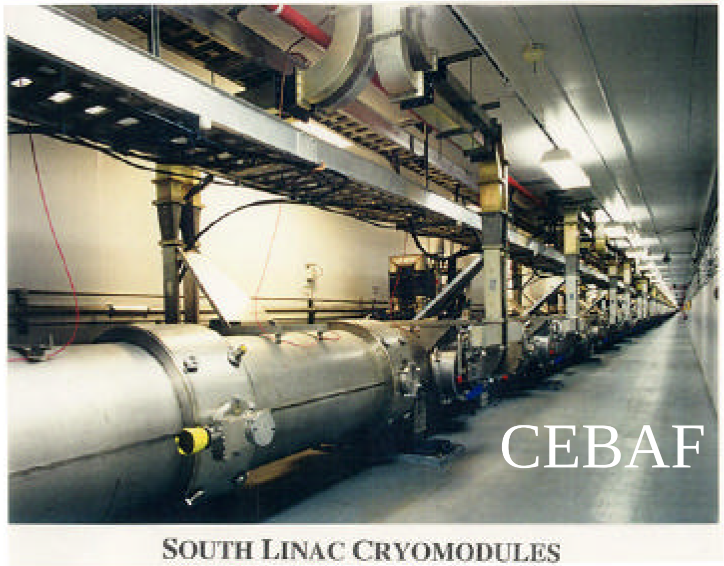
"Livingston Plot for RF Superconductivity"

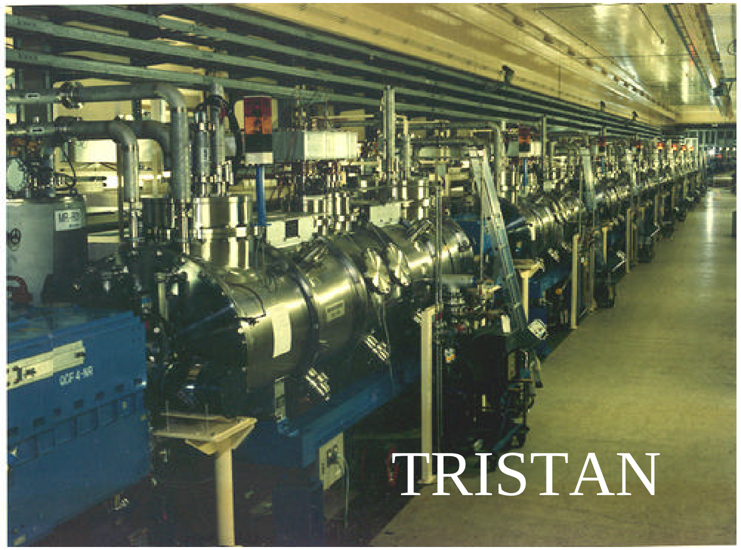
Total Installation > 1000 m
Provided > 5 GV

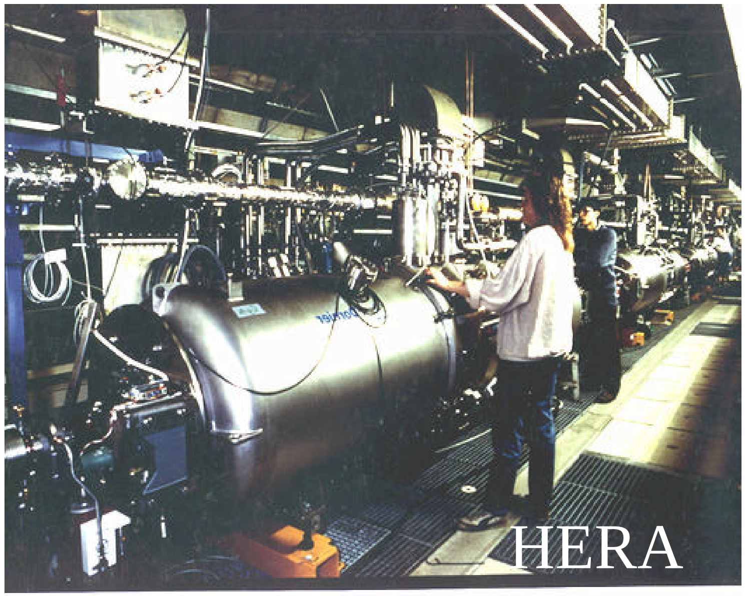


Accelerator Installations at the HEP and NP Frontiers







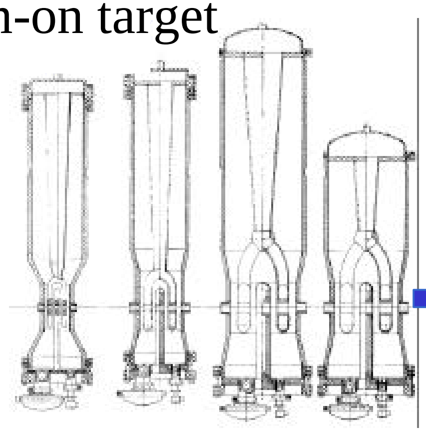


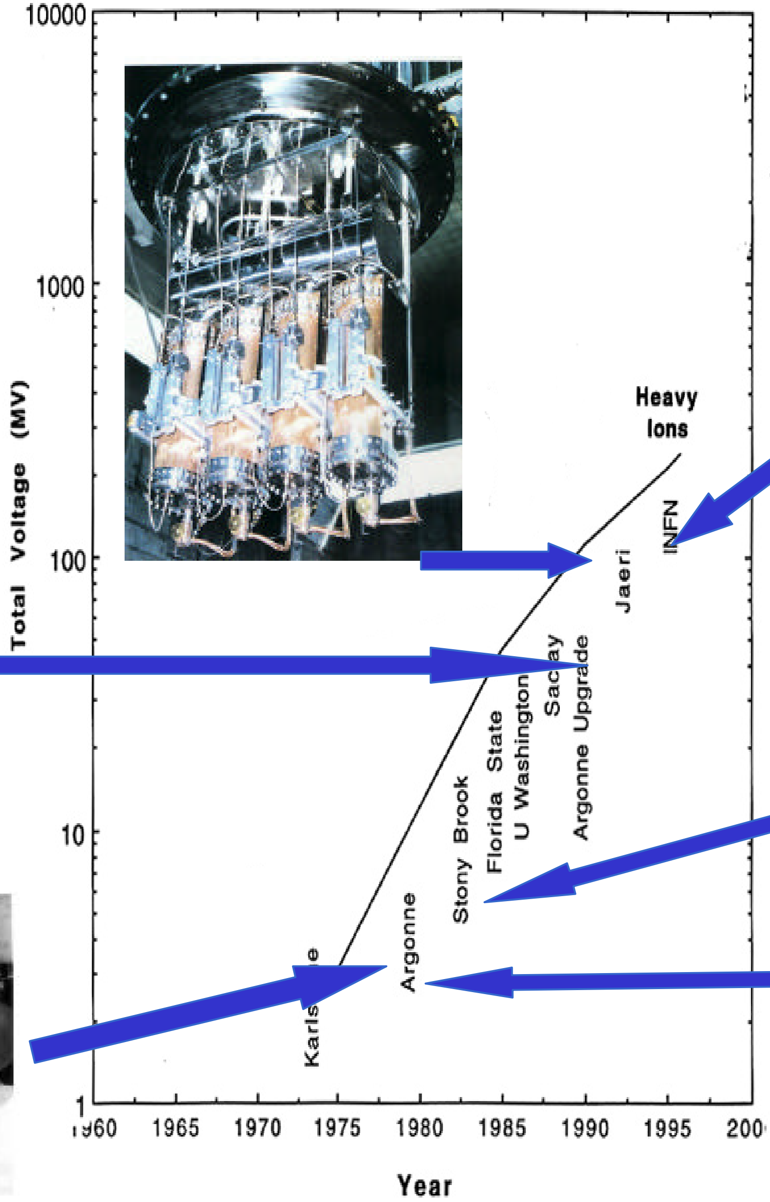
NUCLEAR SCIENCE WITH SUPERCONDUCTING HEAVY-ION ACCELERATORS

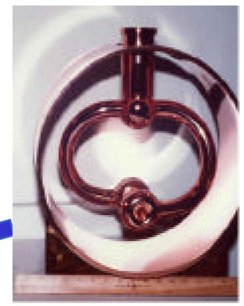
10 Facilities World Wide

> 270 resonators

> 120,000 hours of beam-on target







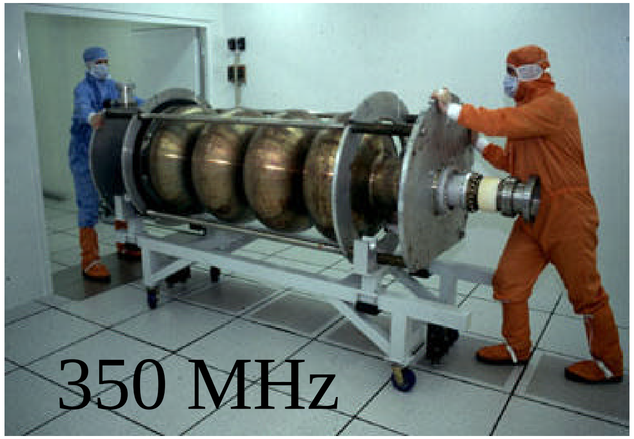
Two Largest Applications
CEBAF and LEP-II (1995 - 2000)

1500 MHz

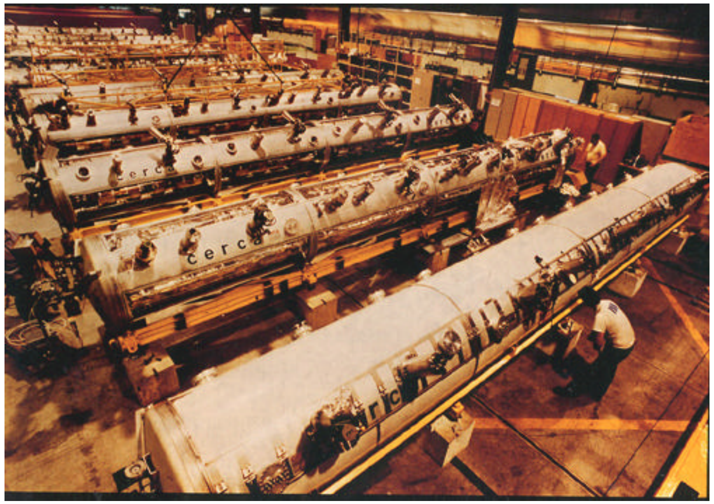
SOUTH LINAC CRYOMODULES

380 cavites, 190 m, 42 cryomodules

Originally designed for 4 GeV, CEBAF achieved a beam energy of 6.5 GeV in five recirculating passes with a CW beam current of 200 μA. Over a period of a few years, CEBAF upgraded their in-line accelerating gradient from the design value of 5 MV/m to more than 7 MV/m.



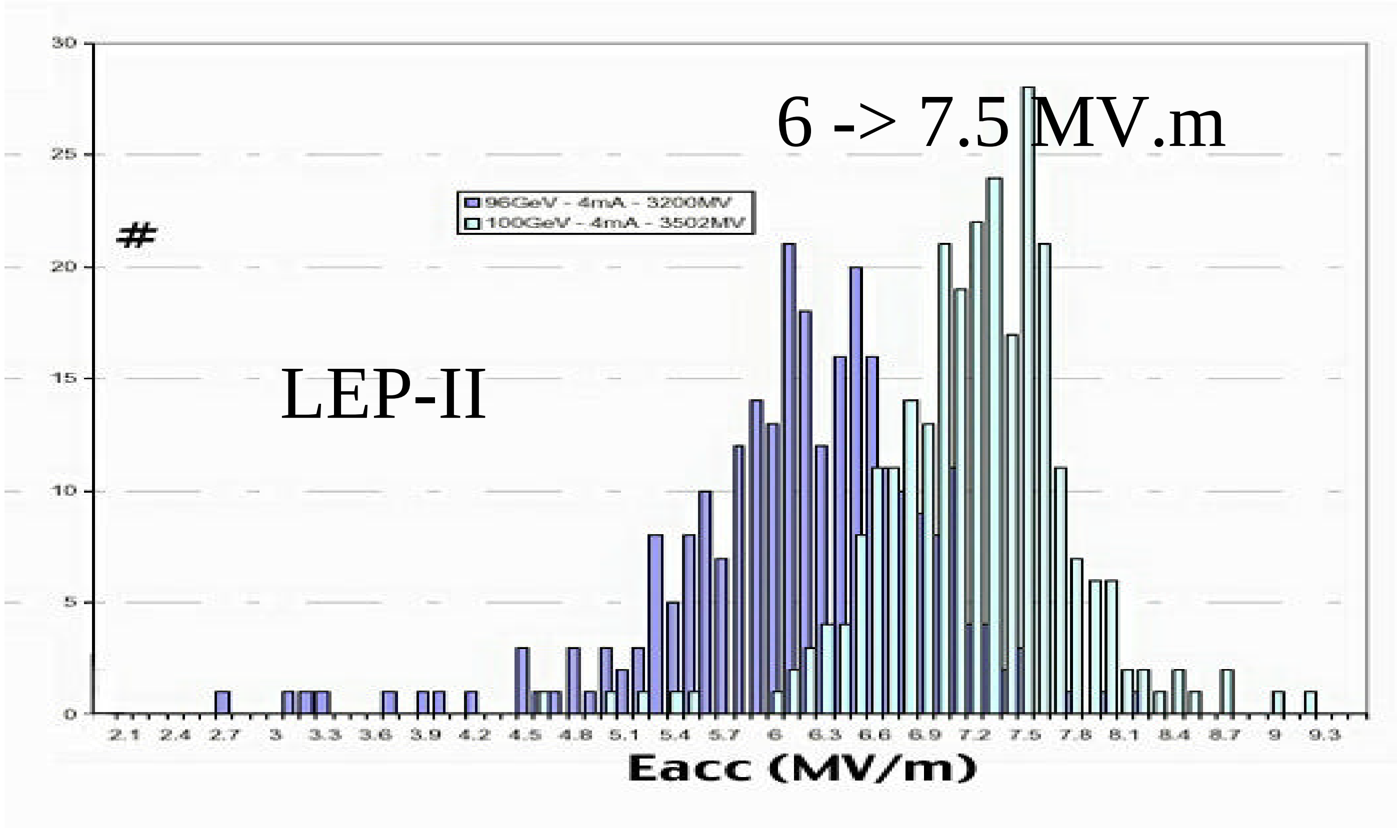
350 MHz

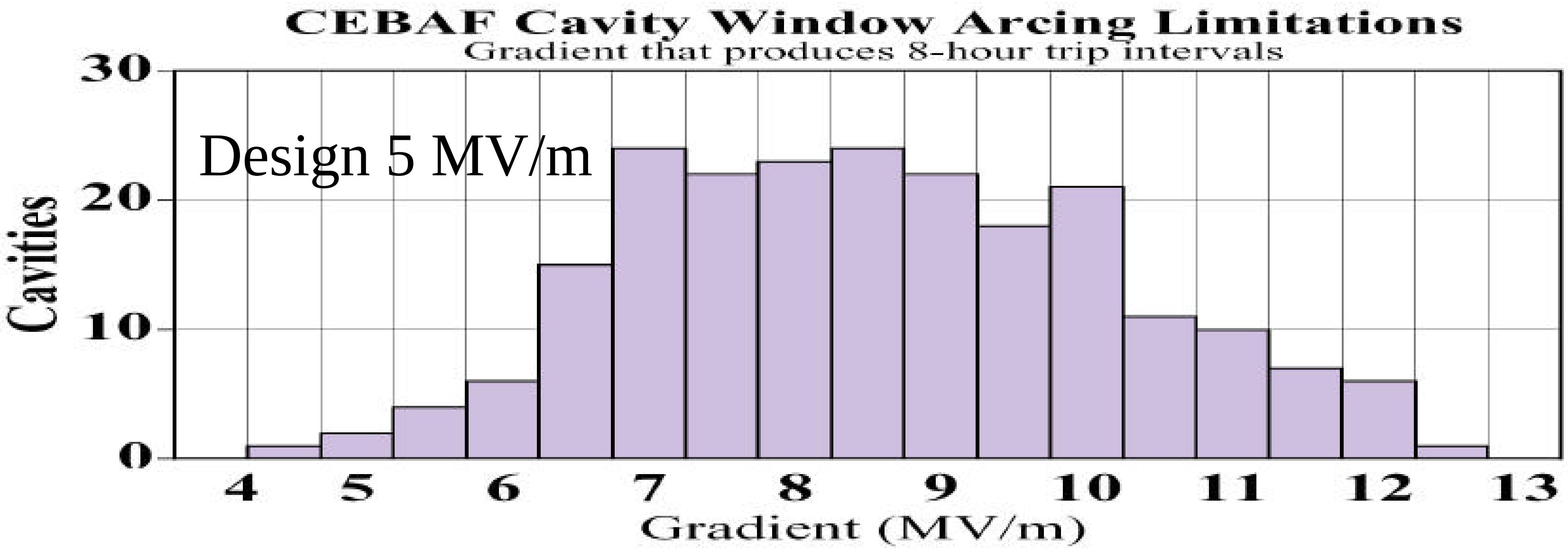


LEP-II , 288 Nb-Cu cavities,

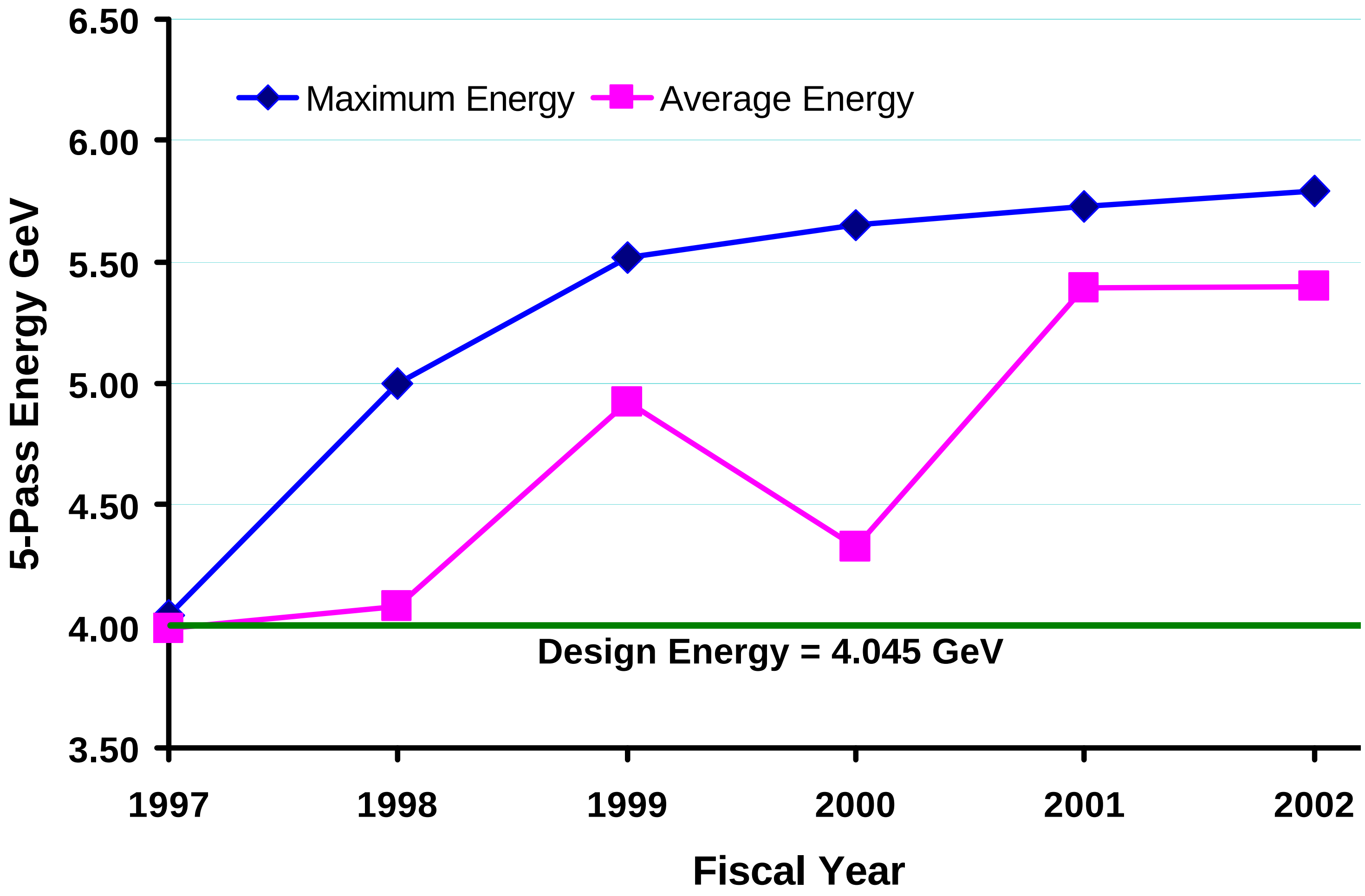
72 modules, 490 m

Operating Gradients

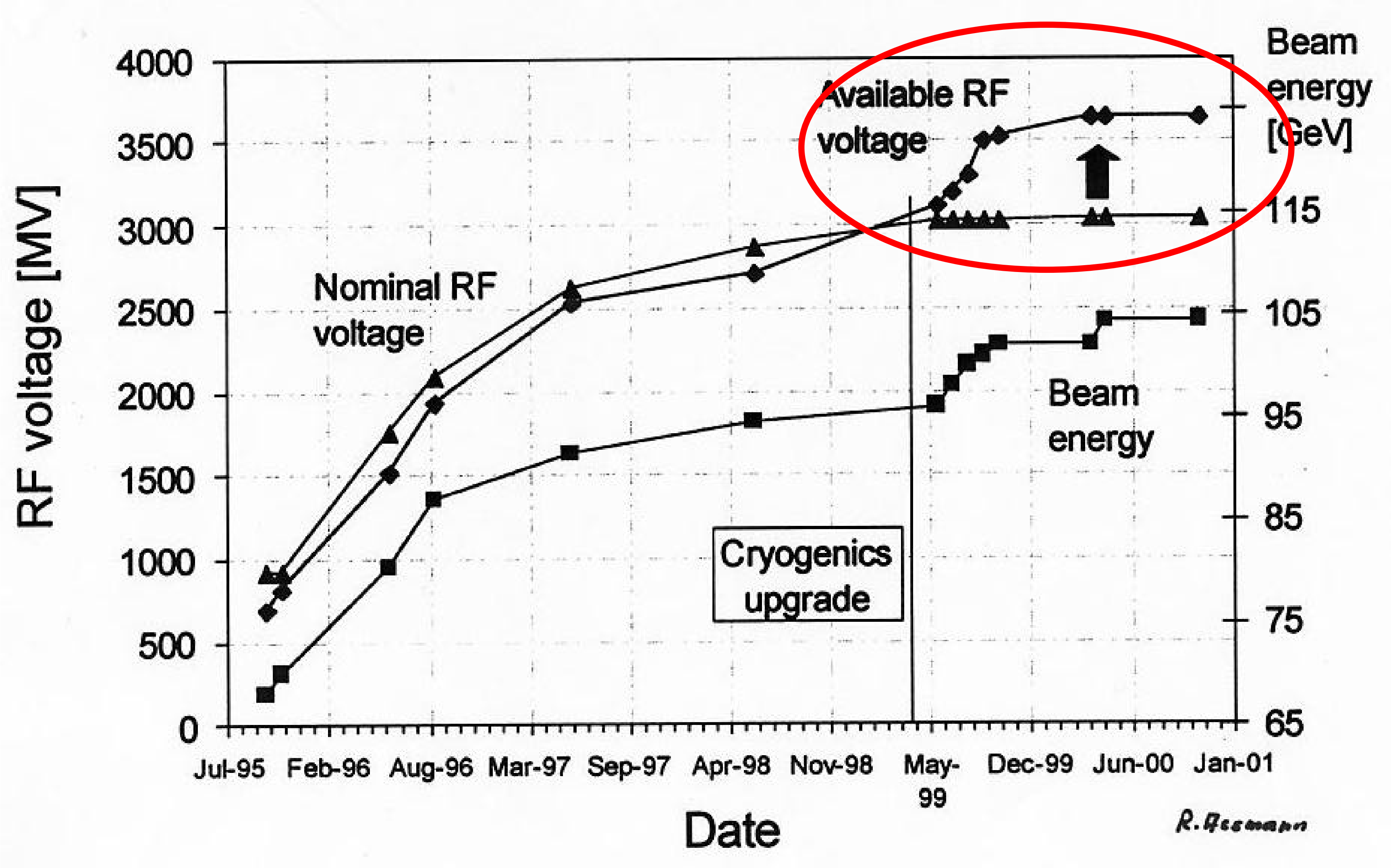




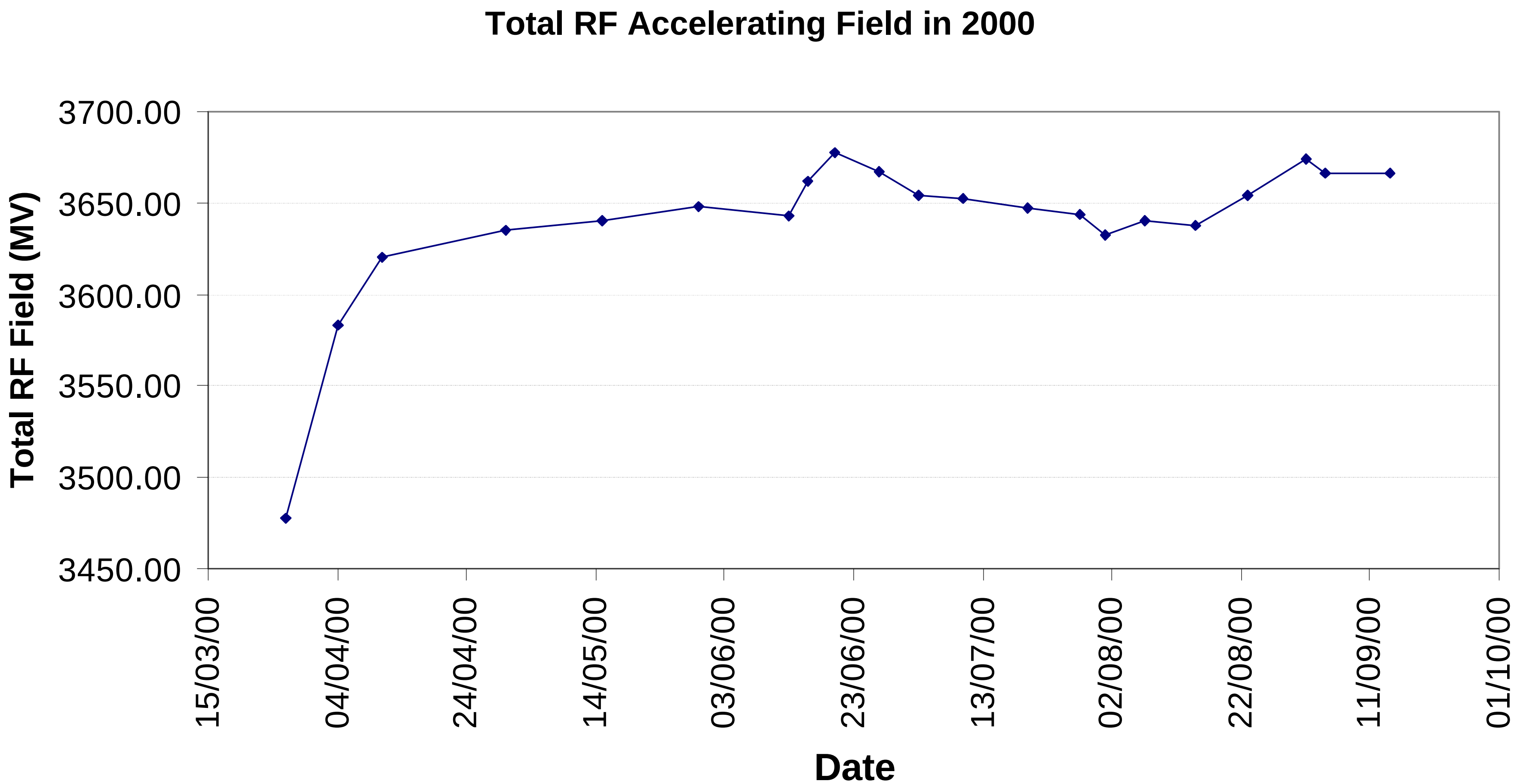
Get more performance from installed cavities - CEBAF



Get more performance from installed cavities - LEP-II

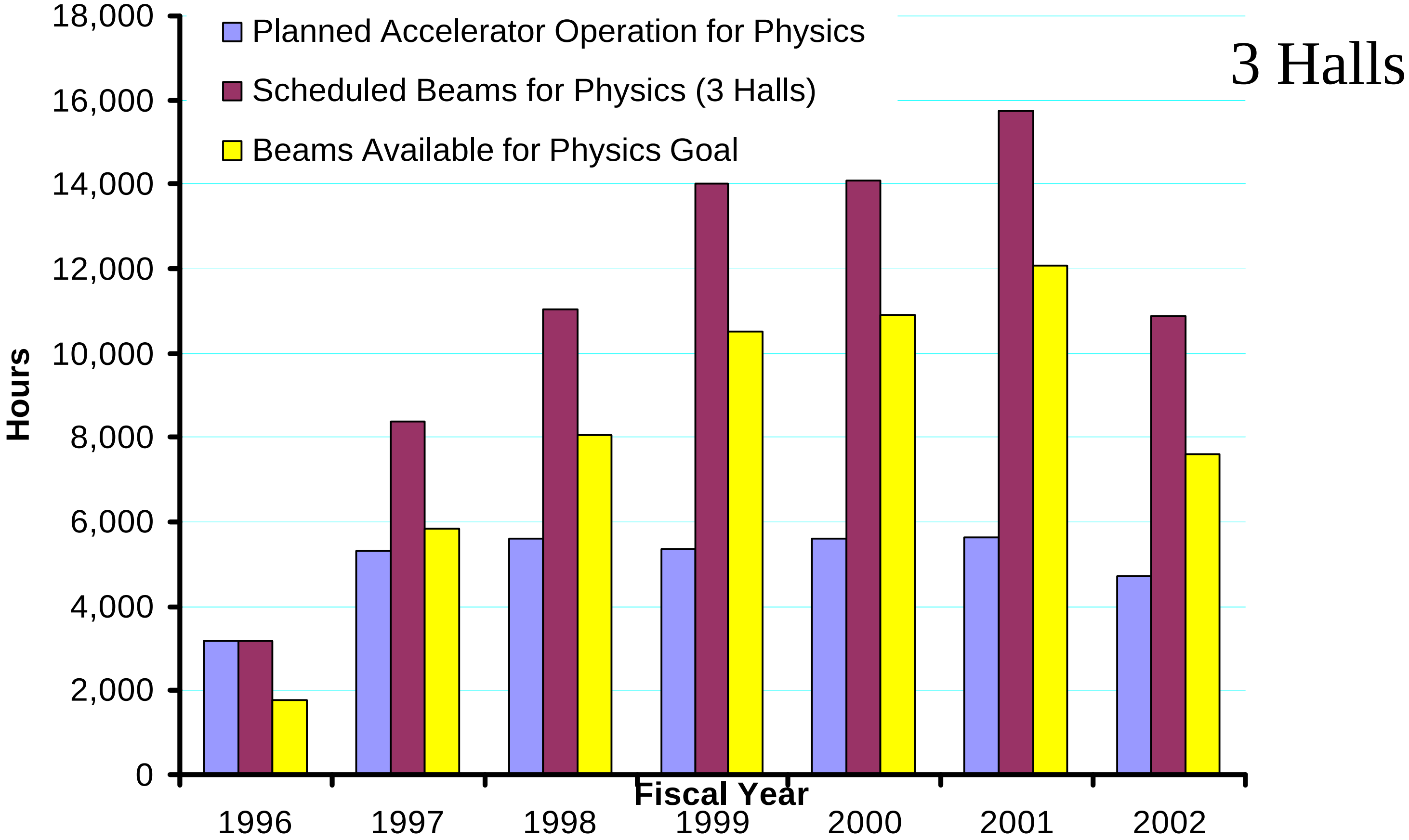


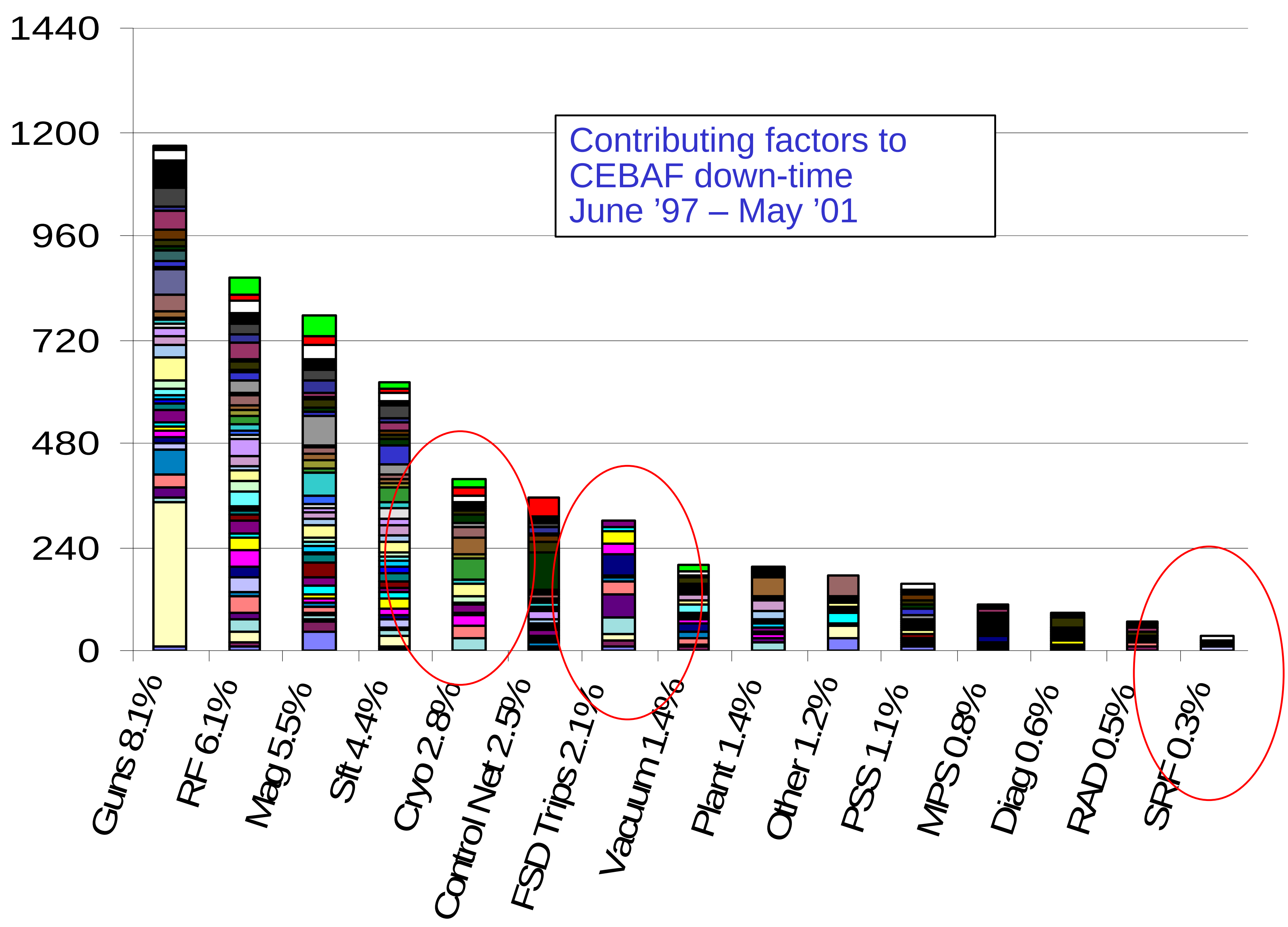
LEP- 2000



Total RF Accelerating Field in 2000
Total RF Field (MV)
3700.00
3650.00
3600.00
3550.00
3500.00
3450.00
15/03/00
04/04/00
24/04/00
14/05/00
03/06/00
23/06/00
13/07/00
02/08/00
22/08/00
11/09/00
01/10/00
Date

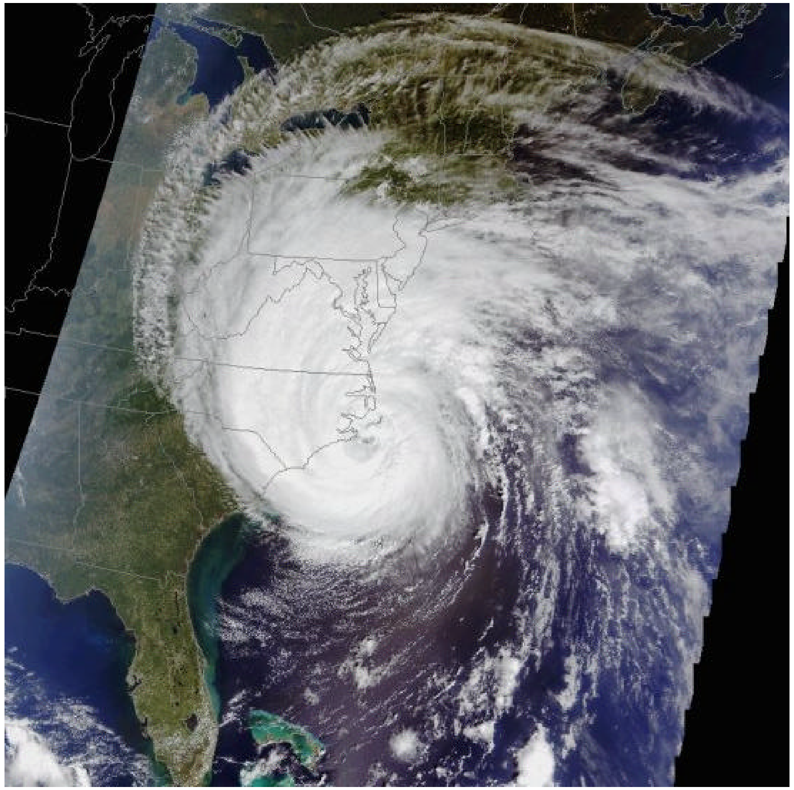
CEBAF Has Accumulated
More than 2000 Cavity-Years of Automated Operation.





Contributing factors to
CEBAF down-time
June '97 – May '01
1440
1200
960
720
480
240
0
Guns 8.1%
RF 6.1%
Mag 5.5%
Sft 4.4%
Cryo 2.8%
Control Net 2.5%
FSD Trips 2.1%
Vacuum 1.4%
Plant 1.4%
Other 1.2%
PSS 1.1%
MPS 0.8%
Diag 0.6%
RAD 0.5%
SRF 0.3%

CEBAF demonstrated robustness of SRF technology with the complete recovery from the effects of Hurricane Isabel - See CERN Courier Feb 2004



Started out as a Category 5 hurricane

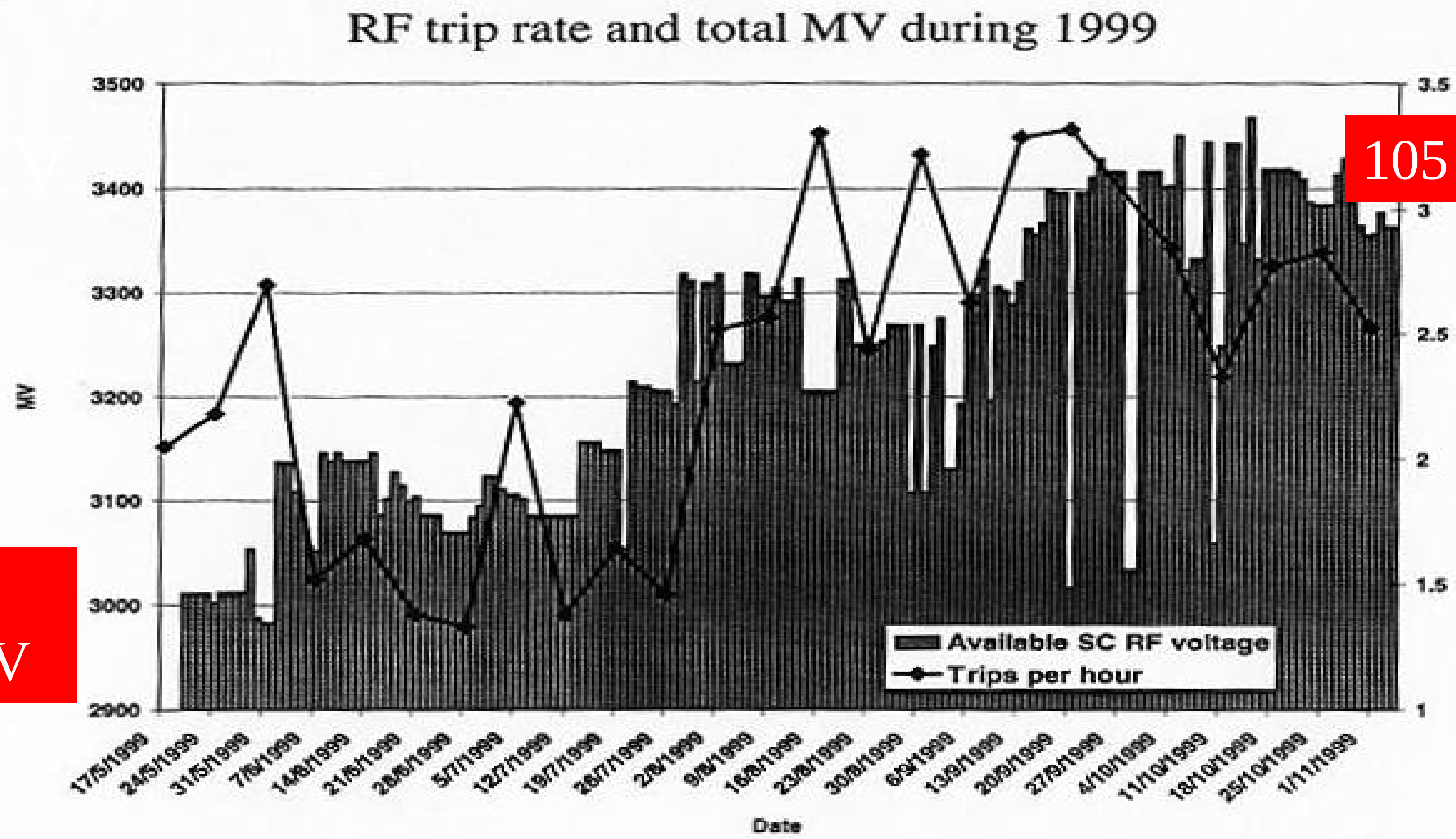
Caused 3.5 day region wide power outage. --> Warm up.

Physics program re-started within 6 weeks

< One percent of cavities could not be powered up due to poorer vacuum

All these cavities are inside a single cryomodule

LEP2: Always pushing the gradient up



105 GeV

98 GeV

1 rf trip ≡ 1 klystron off

≡ − 100 MV

(≡ − 0.8 GeV)

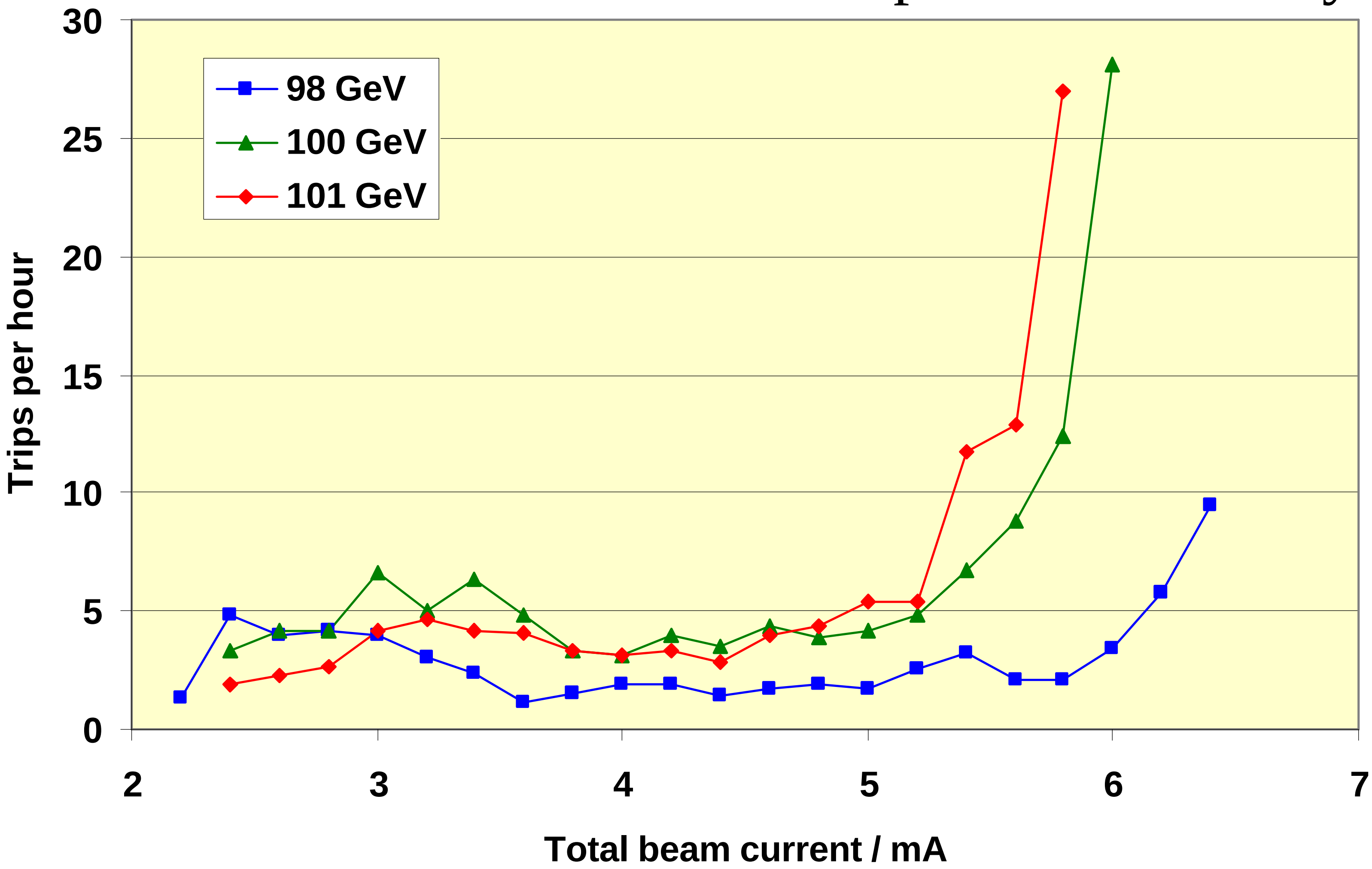
LEP RF A.Butterworth/G.Geschonke

LEP2

Limitations:

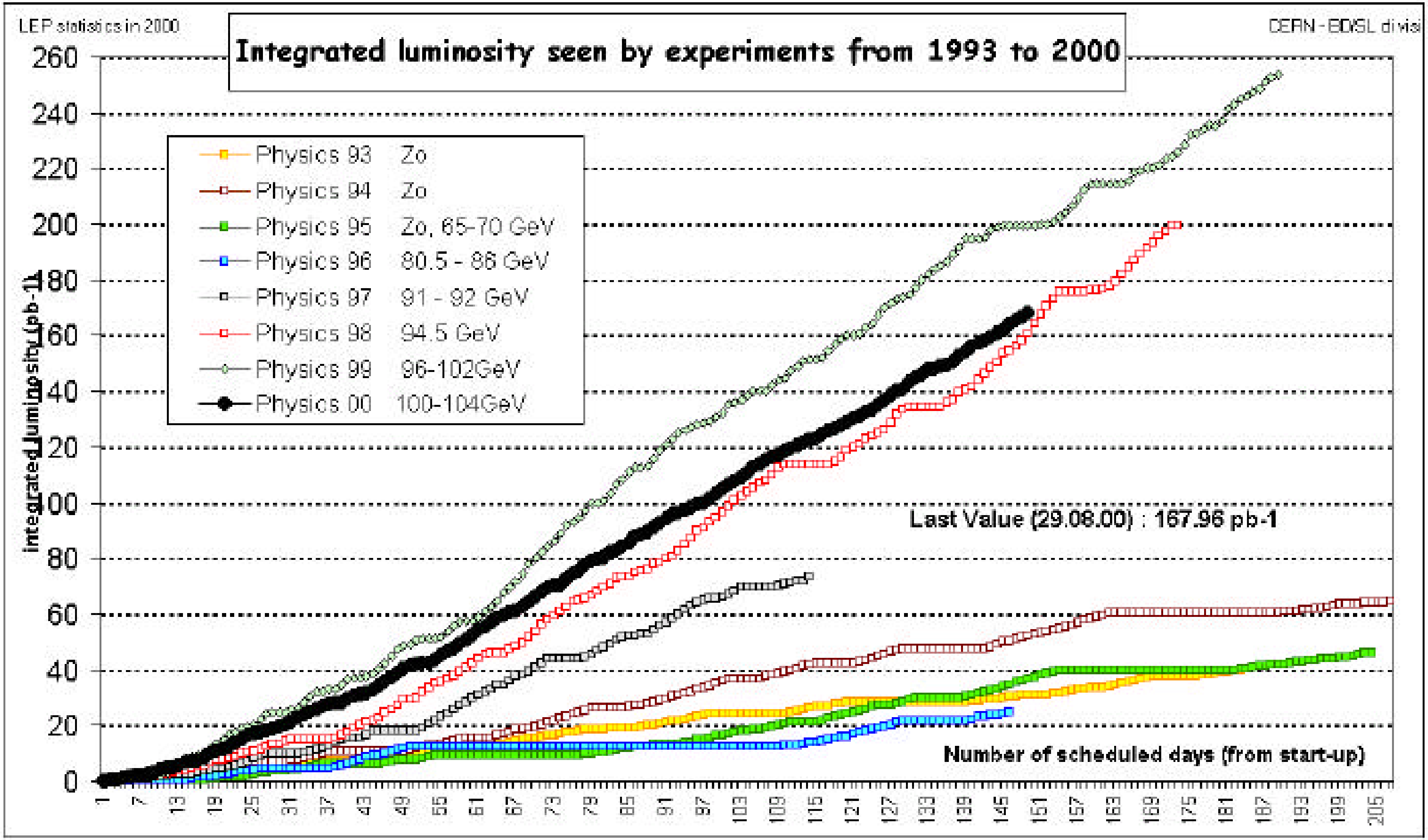
1 trip = loss of one klystron=
-100 MV

Influence of beam current on operational stablity:



pb-1

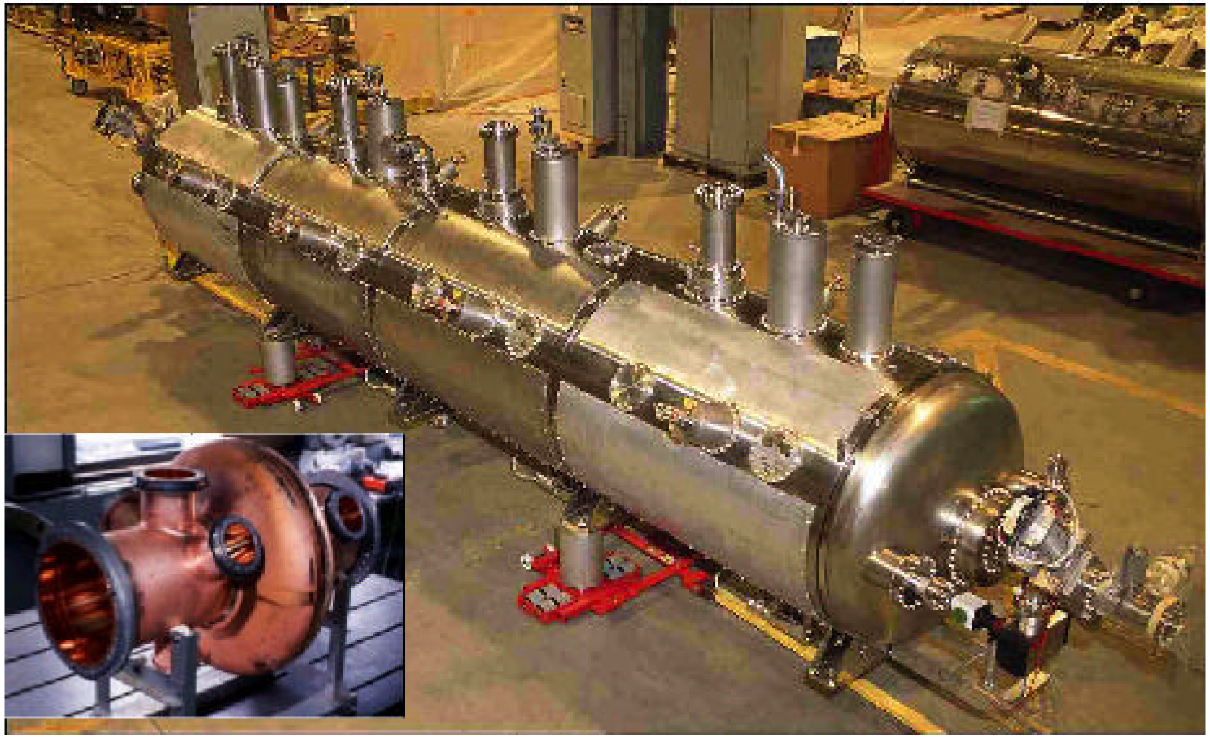
LRP2 Integrated Luminosity : 1993 - 2000



200 days

Future SRF Activities at CERN

- SRF is Ready for LHC
- \+ Multi-mission High Intenisty Proton linac (later)



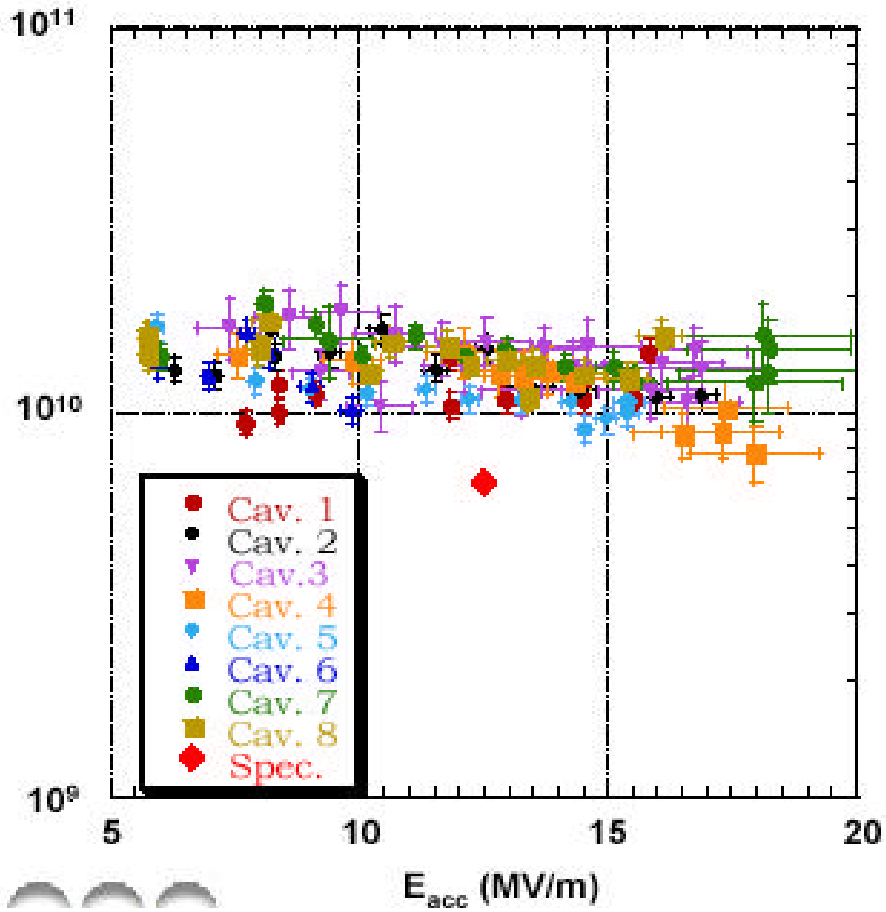
16 Nb-Cu Cavities

4 Cryomodules

16 MV per beam

180 kW per cavity

Future CEBAF: 12 GeV Upgrade
& More (later)
Higher Gradients

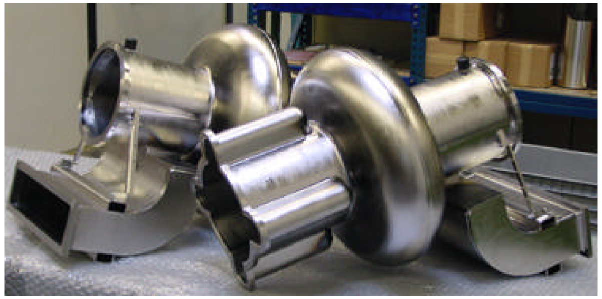


SRF For High Luminosity, High Current Storage Rings

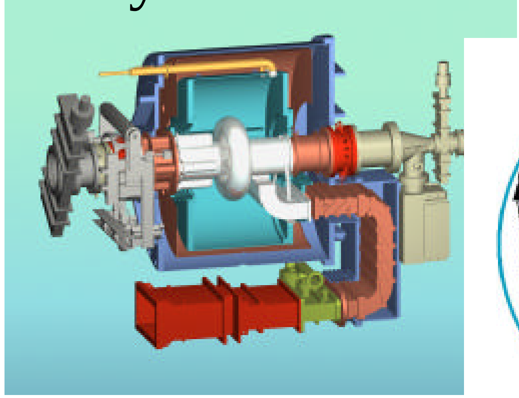
- CESR & KEK-B
- 500 MHz, 7 - 8 MV/m
- Beam currents " 1 amp
- Beam power 250 - 380 kW/cavity CW

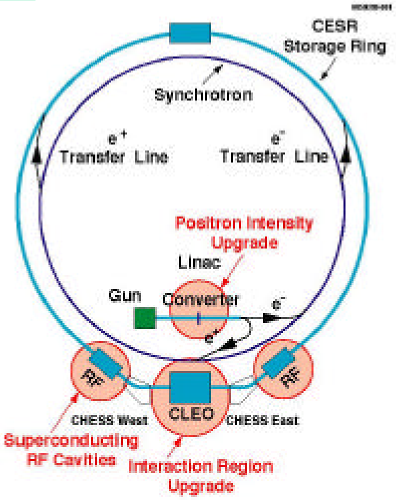
CESR, KEK-B 500 MHz, 7 - 8 MV/m, > 1998

Between 1998- 2003 the availability of CESR was 84 - 95% of scheduled operating time

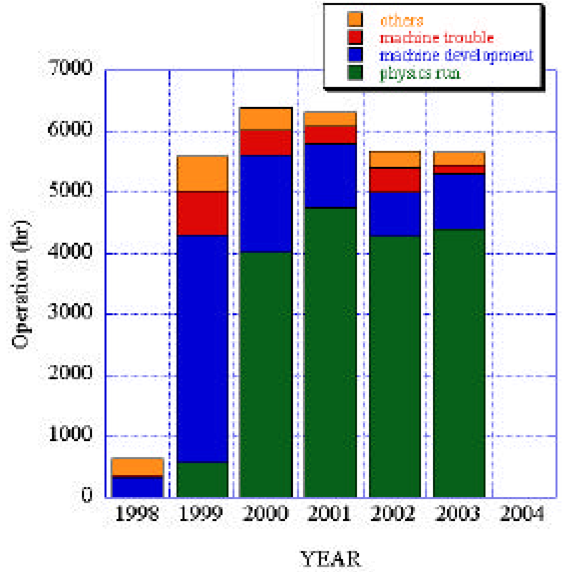


4 systems

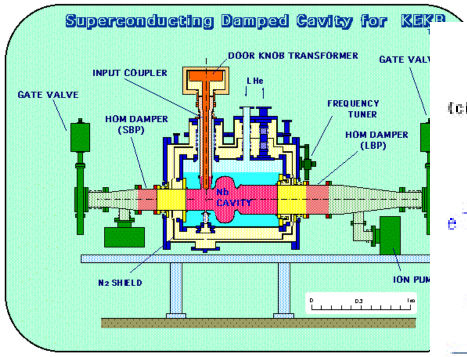


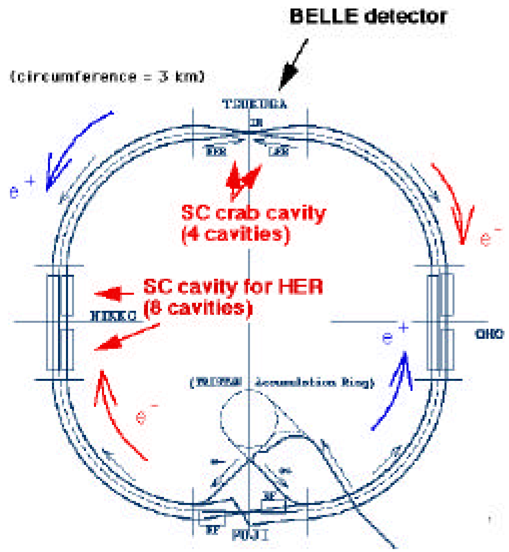


Between 2000 - 2003 the availability of KEK-B was 88 - 94% of scheduled operating time

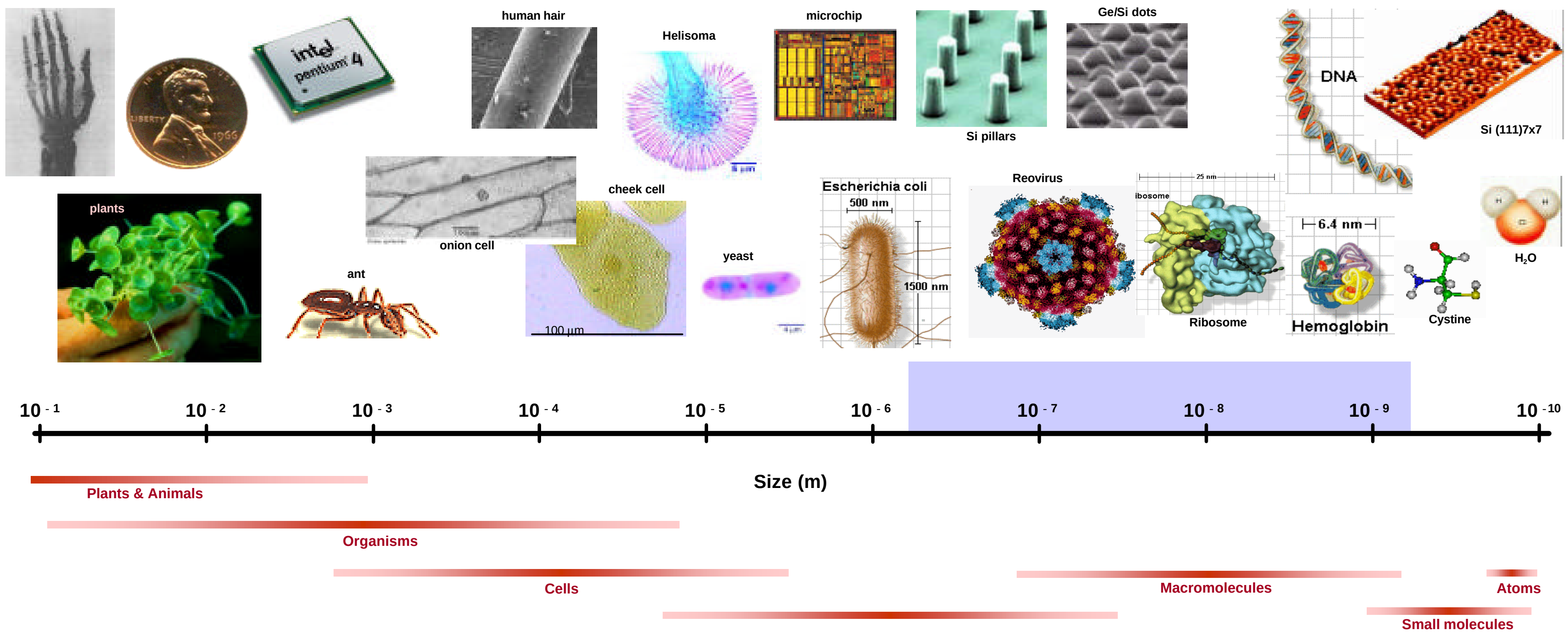


8 systems



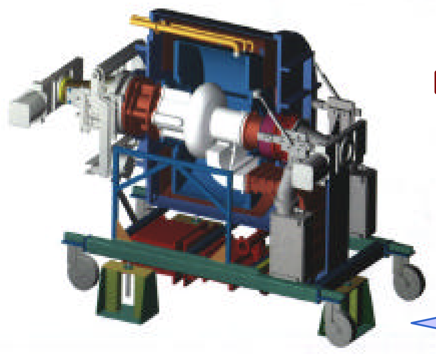


SRF for Light Sources



Storage Ring Light Sources

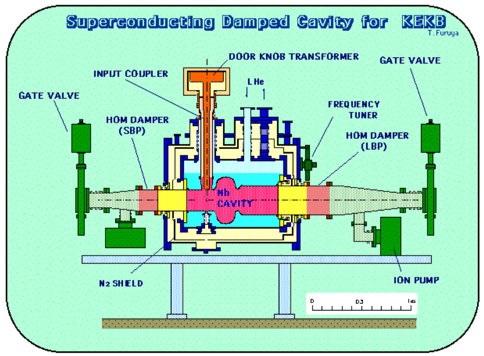
Cornell has transferred CESR SRF technology to ACCEL which is providing turnkey, tested systems for major storage ring light sources around the world with guaranteed performance. Total 9 systems



Technology transfer

ACCEL

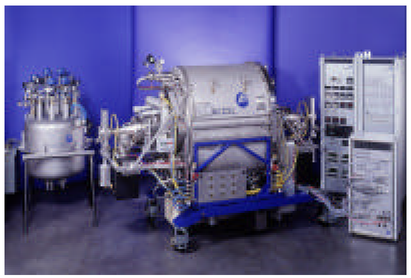
CESR-c



Turn-Key Systems

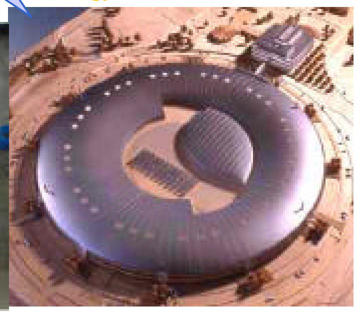
Taiwan Light Source

National Synchrotron Radiation Research Center



Canadian Light Source Inc.

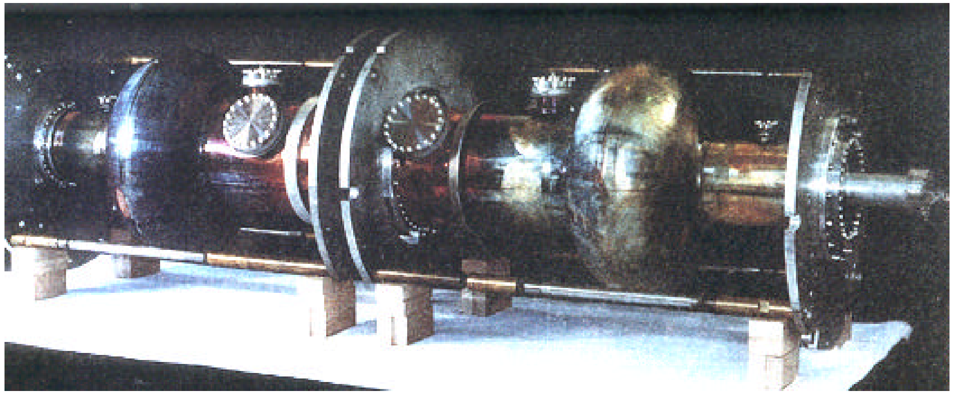
diamond



KEK/Mitsubishi will deliver 2 turnkey systems to BEPC in China

Saclay-CERN

A 2.75 GeV, 500 mA Light Source



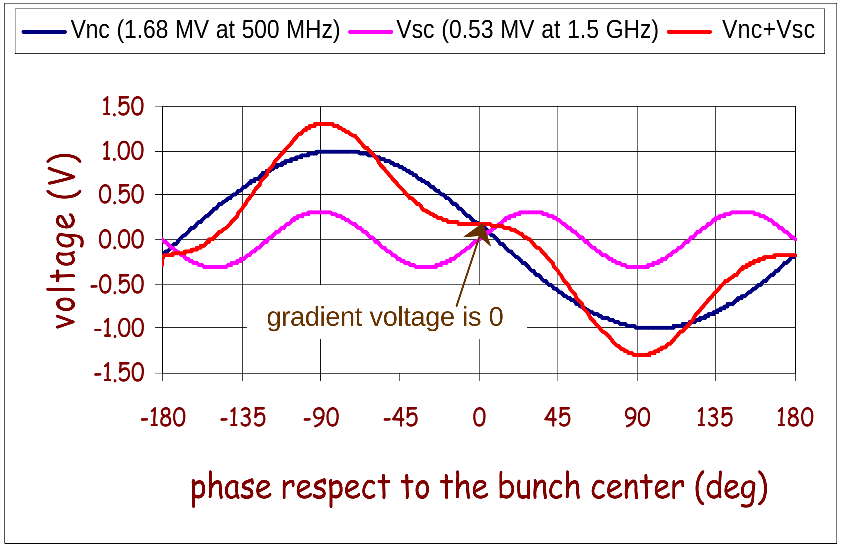
Module tested at ESRF to Eacc of 7 MV/m and transferred

360 kW to 170 mA beam.

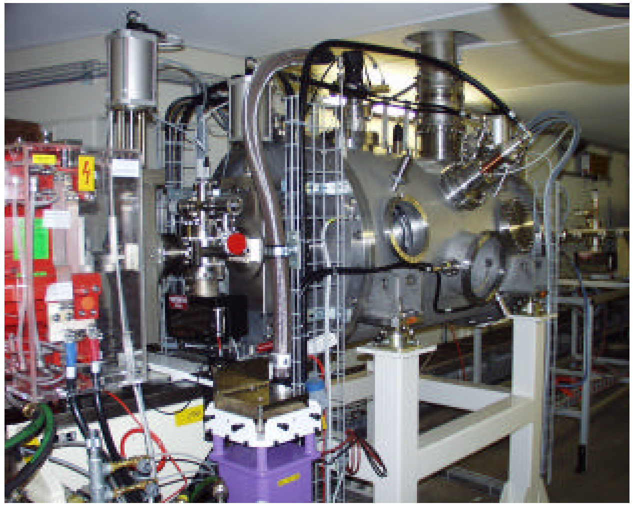
Third Harmonic Passive Cavity-Systems Installed

3rd harmonic (1.5 GHz) SRF systems lengthen bunch, decrease charge density & increase beam lifetime. Landau damping suppresses coupled bunch instabilities.

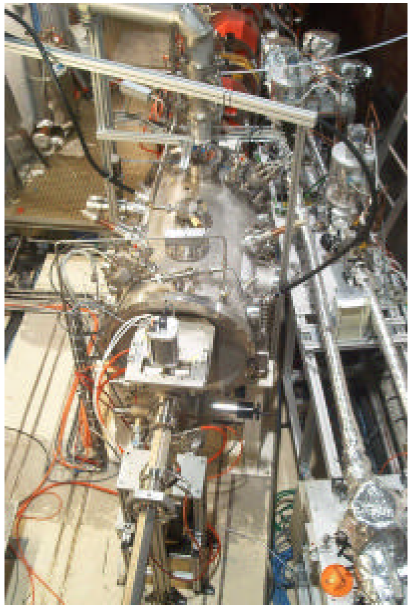
After installation, both SLS and ELETTRA gained a factor of 3 on bunch lengthen and more than a factor of 2 on beam life-time.



Prototype 3rd harmonic Cavity
Built at CERN

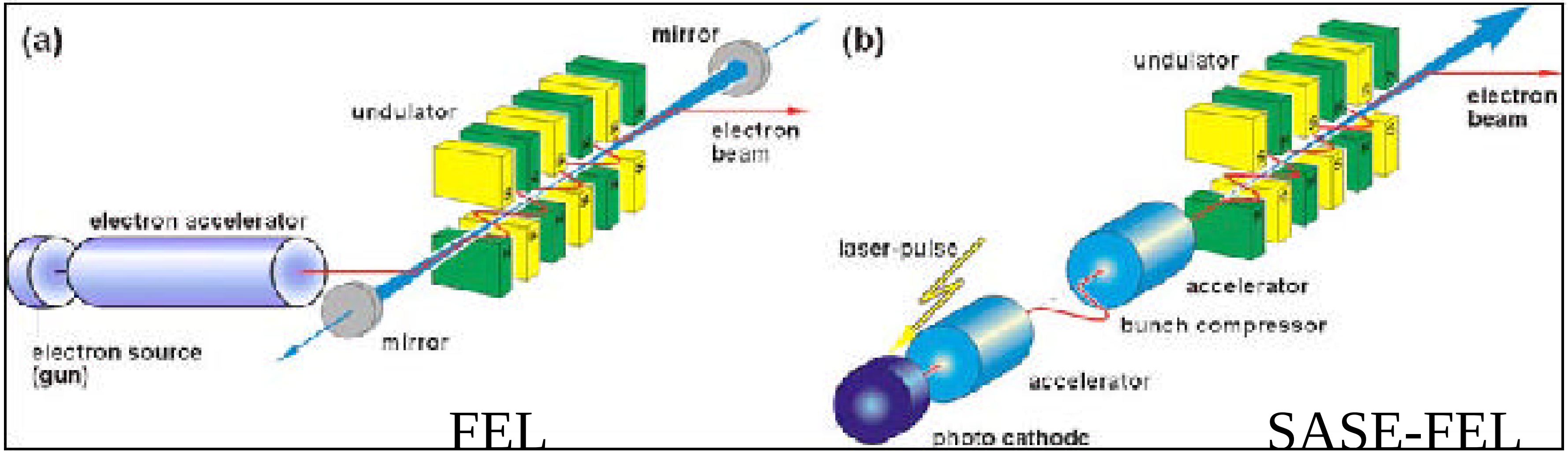


SLS Cryomodules

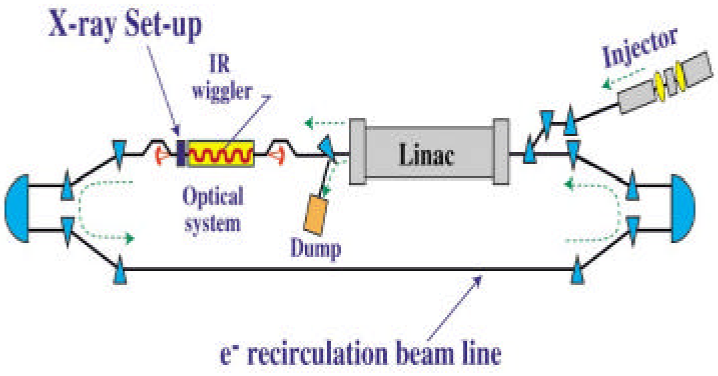


ELETTRA Cryomodule

FREE ELECTRON LASERS



FEL SASE-FEL

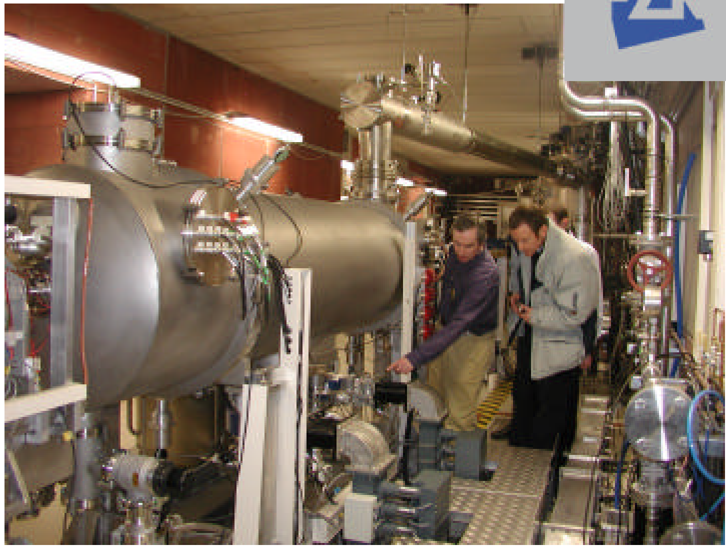


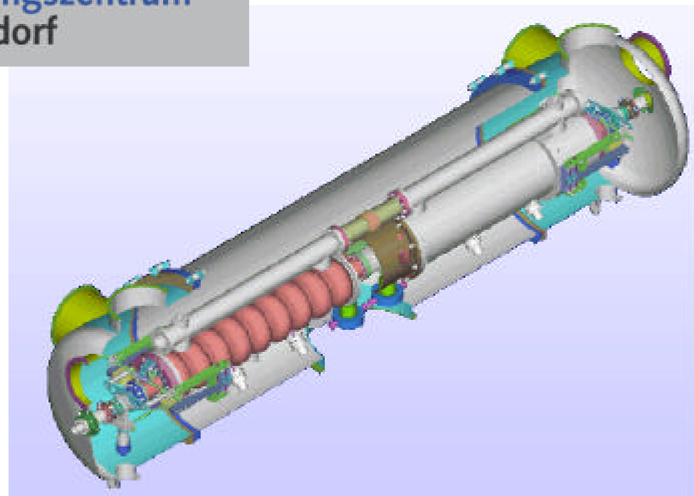
Energy Recovery Linacs (ERL)

Six Operating Light Sources

	E (MeV)	Wavelength (um)	
JAERI - Japan	16	20 - 30	ERL
ELBE Rossendorf-Germany	12 – 40	2 - 10	FEL
SCA- Stanford, USA	40 – 50	1 - 2	FEL, ERL
DALINAC Darmstadt-Germany	40 – 50	2.5 - 7	FEL
JLAB- Va, USA	45 – 80	1 - 6	FEL, ERL
TTF-I – DESY, Germany	180 - 270	0.1 – 0.2	SASE-FEL

Forschungszentrum Rossendorf





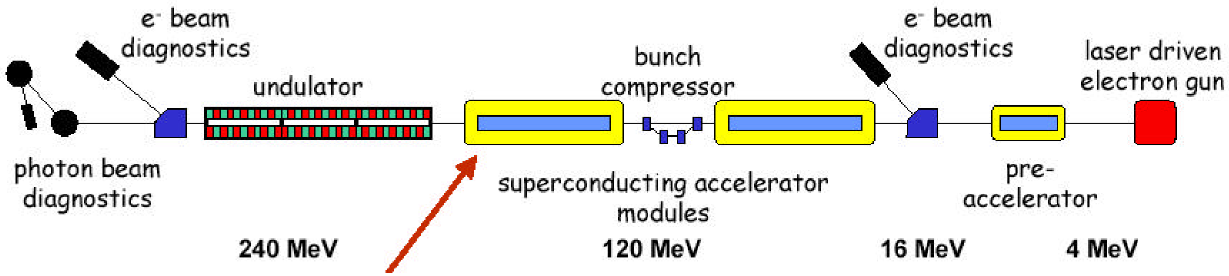
1300 MHz TESLA Cavities

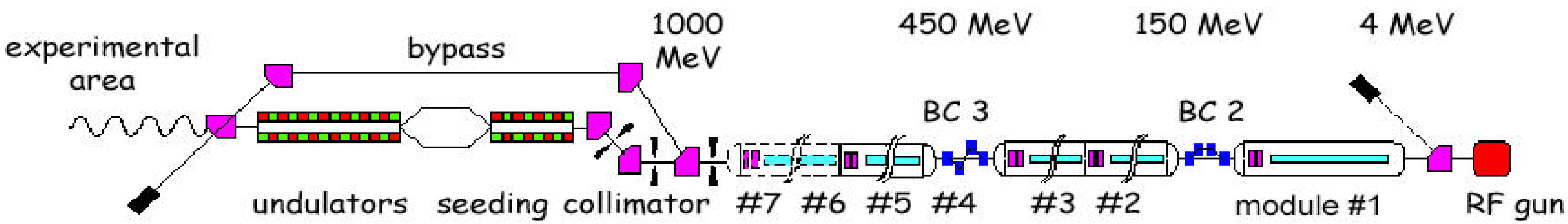
Jefferson Lab

FEL Upgrade 8 cavity module
Average Eacc > 15 MV/m
1500 MHz

August 03. String assembled and under vacuum in the clean room.

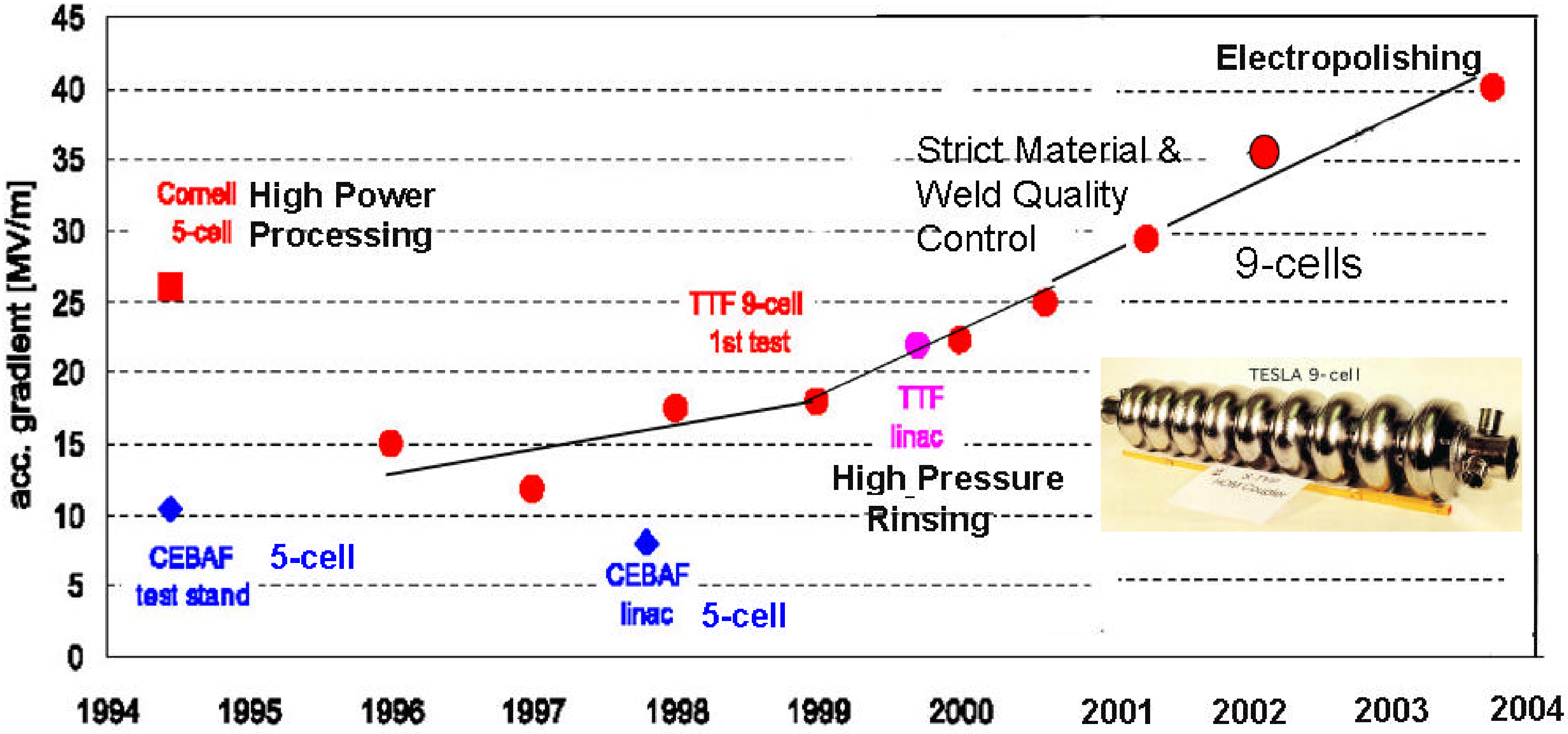
TTF-FELs



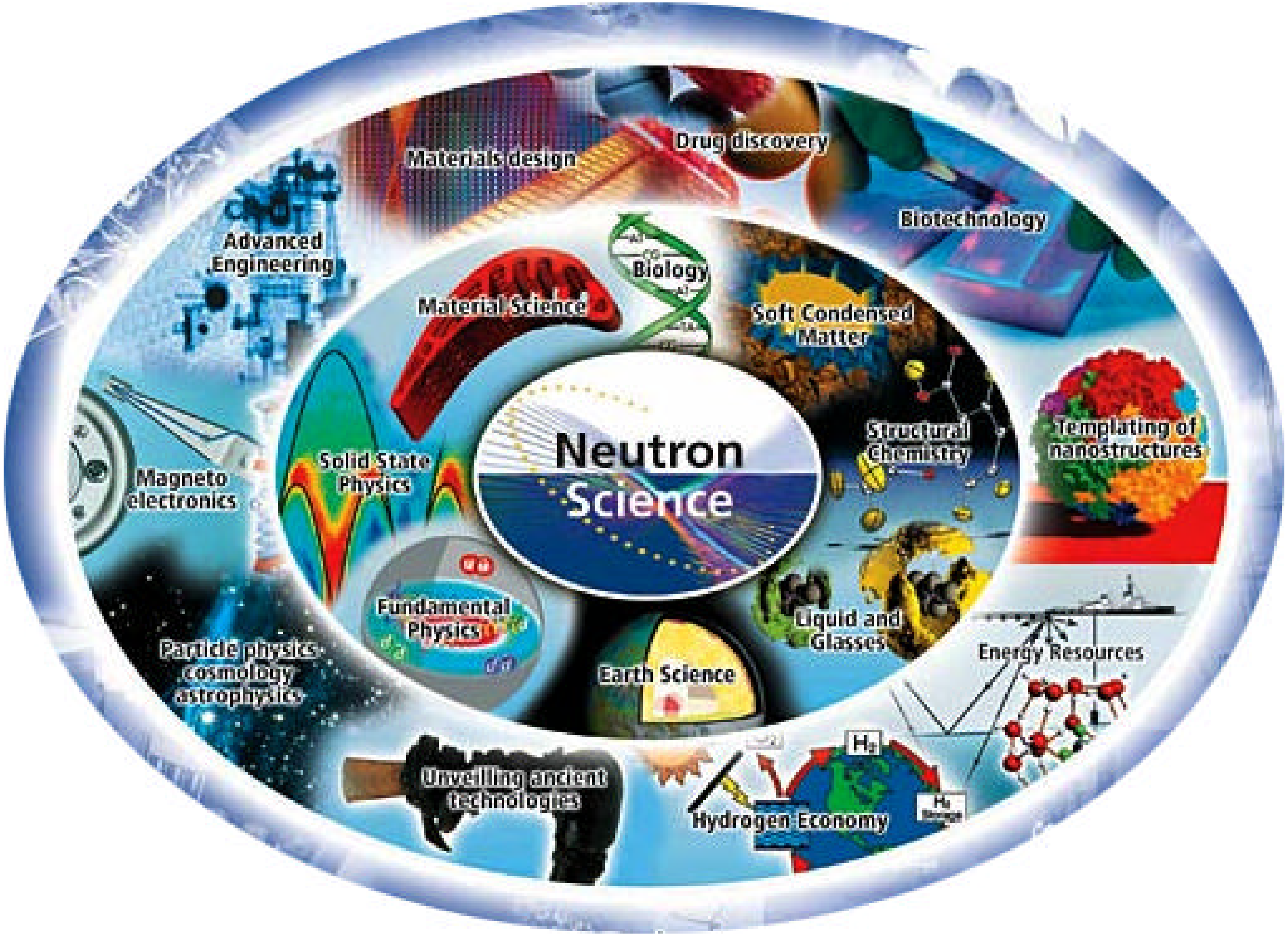


TTF-II

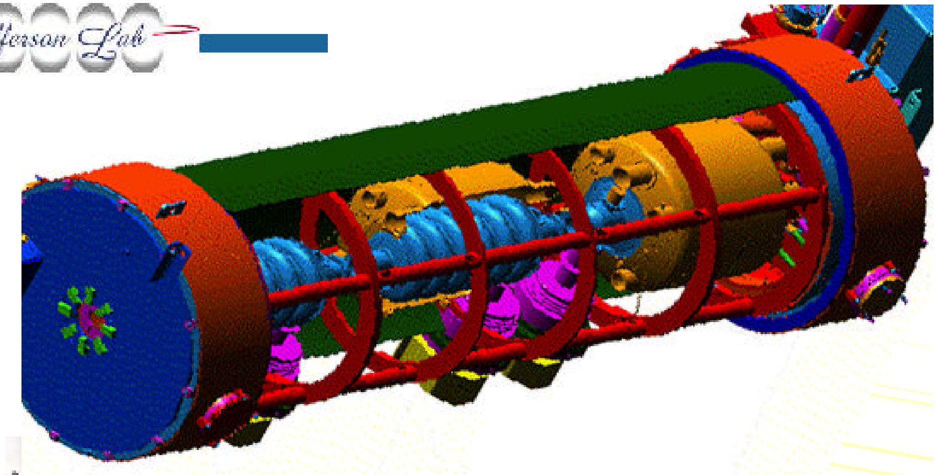
Gradient Progress for TESLA and TTF Success Has Stimulated Many World-Wide SC Accelerators

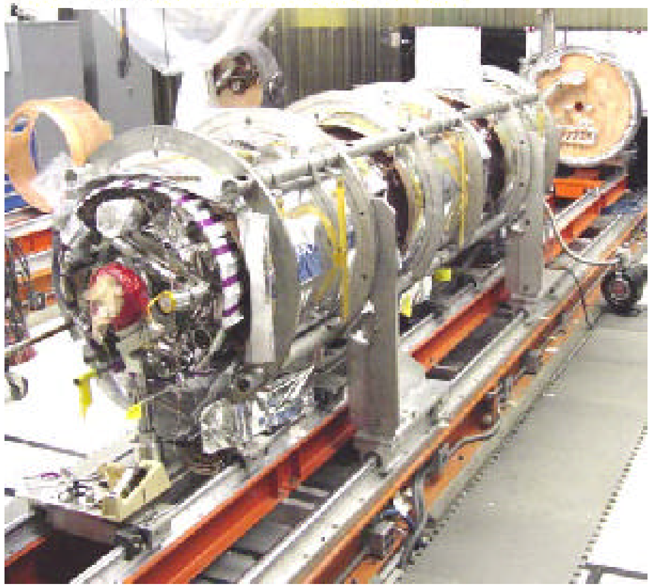


ACCELERATOR-BASED NEUTRON SOURCES



SNS: First High Intensity Superconducting Proton Linac, Switched to SC in 2000



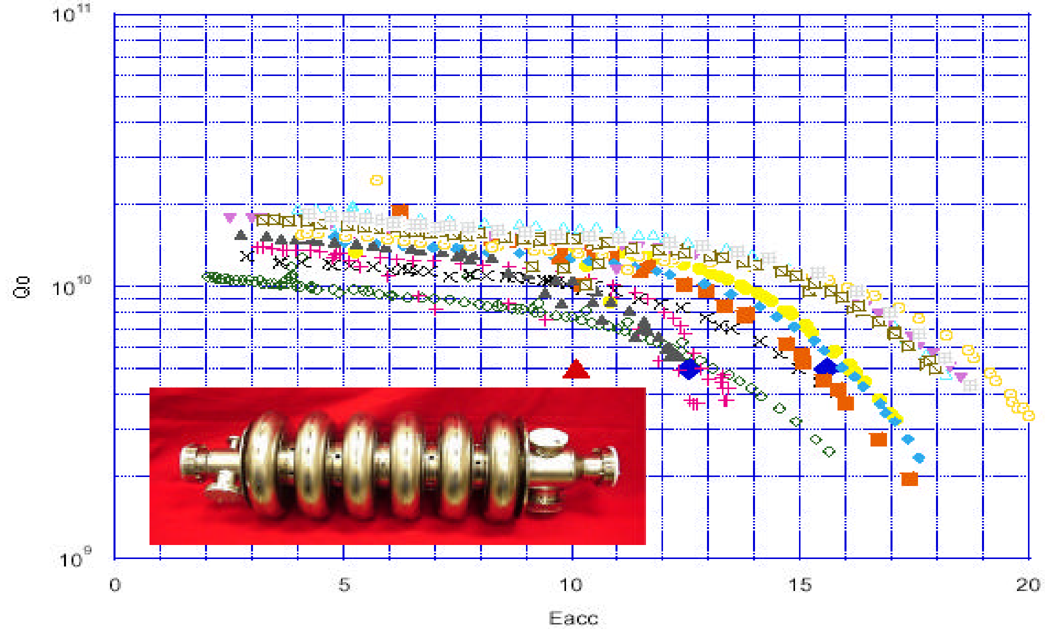


8 completed

6 cryomodules

installed at SNS

Performance of SNS Structures, JLAB

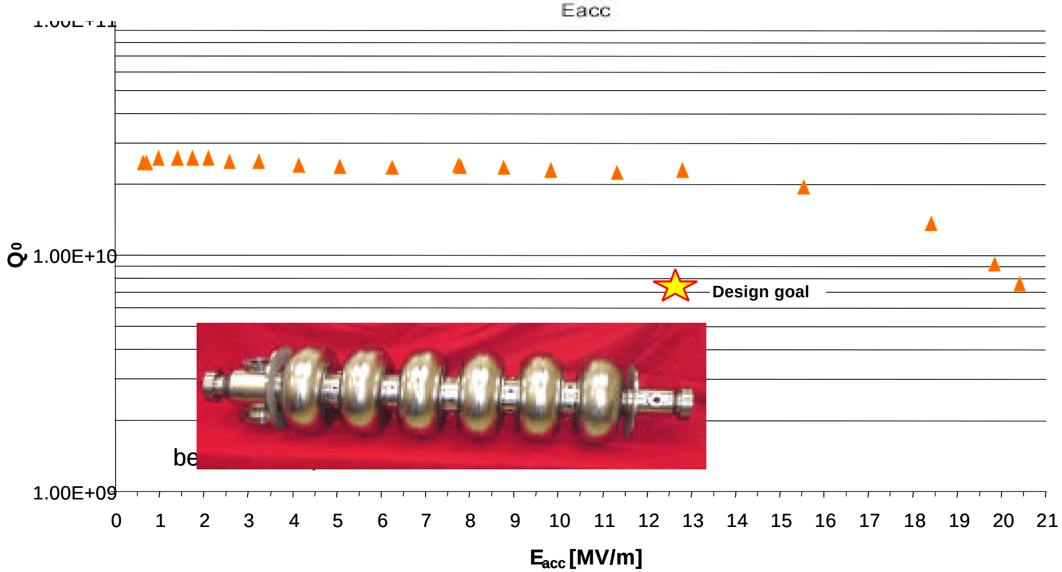


> 30 cavities made by industry

Peak surface electric fields in medium beta elliptical structures are now in the range of 50 - 70 MV.m, comparable to TESLA structures.

β = 0.61, 805 MHz,

Epk/Eacc = 3.5



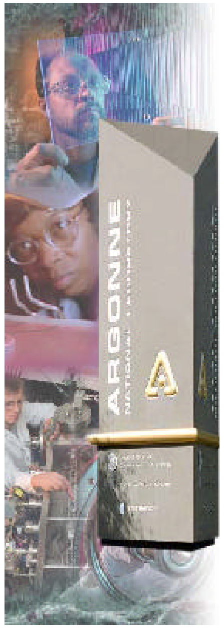
> 30 cavities made by industry

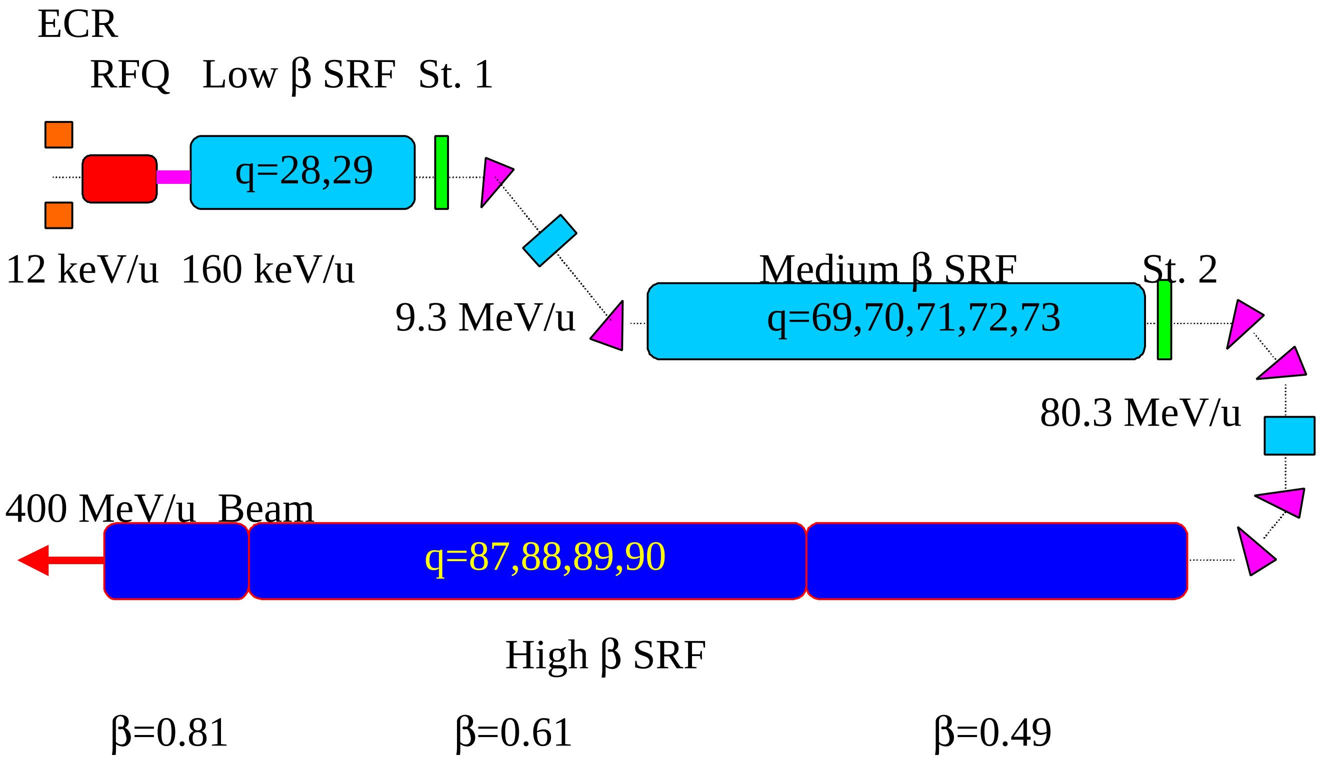
β = 0.8, 805 MHz,

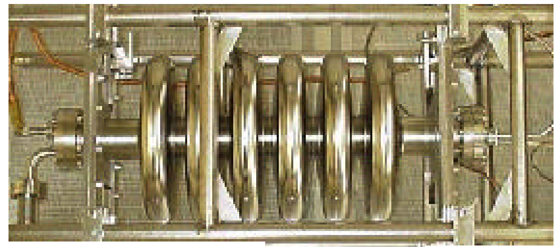
Epk/Eacc = 2.5

Rare Isotope Accelerator (RIA) for Nuclear Astrophysics

High Priority for Nuclear Physics



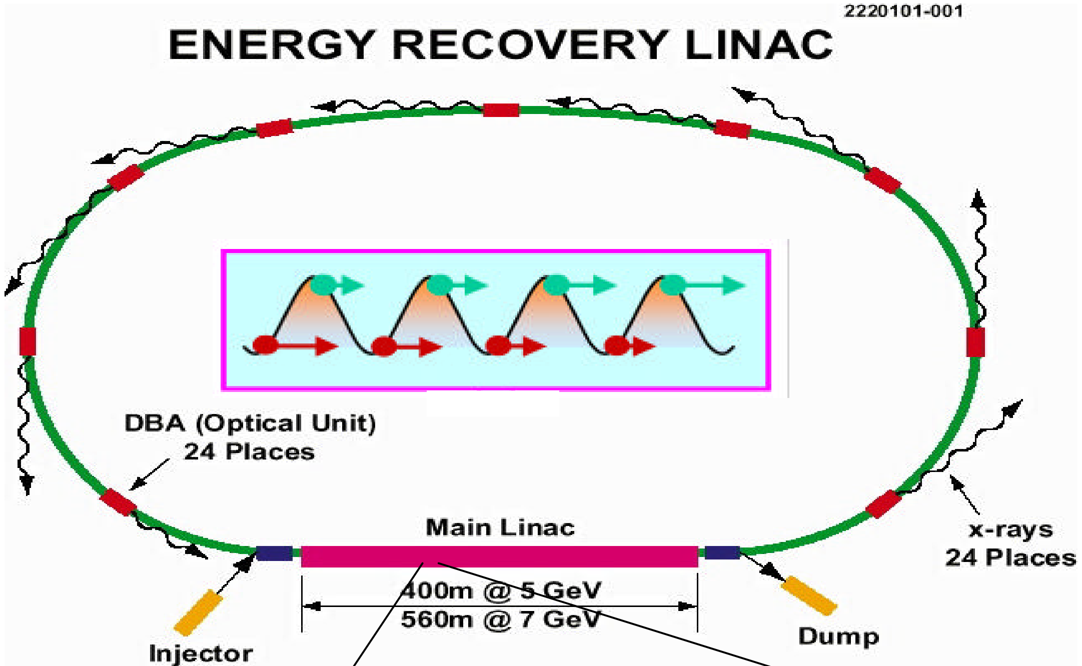


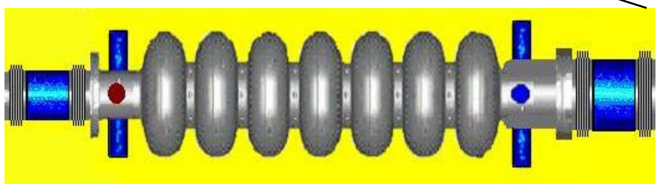


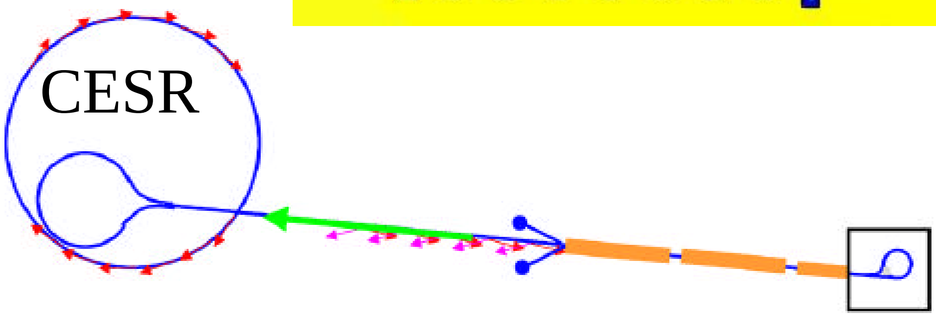
Future Light Sources Under Study Most Based on TESLA Technology

- USA
  - Cornell - ERL 5- 7 GeV, ERLPrototype 100 MeV
  - BNL, PERL, 2.7 GeV
  - LBNL - LUX, 600 MeV
  - MIT - 1 - 4 GeV
- UK-Europe
  - BESSY: 1.5 - 2.2 GeV
  - Daresbury, 4 GLS, ERL, FEL, 600 MeV,
    - Prototype 30 MeV
- Japan
  - KEK, 4 - 6 GeV, ERL

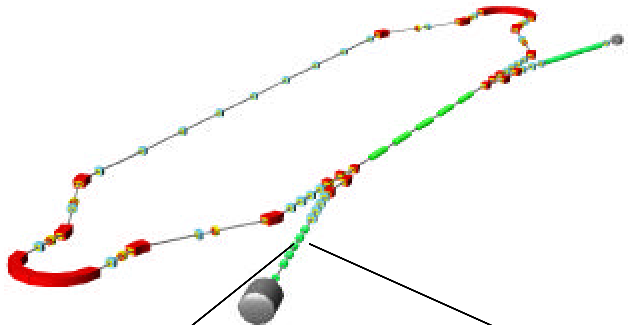
Cornell

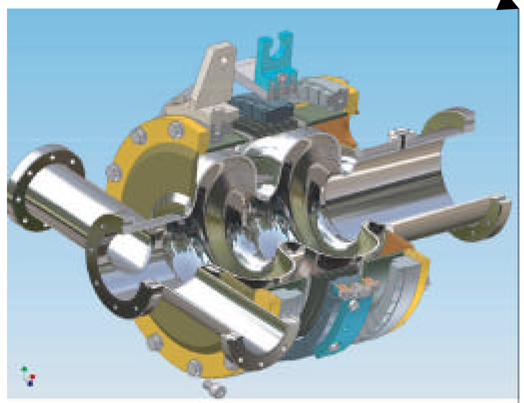






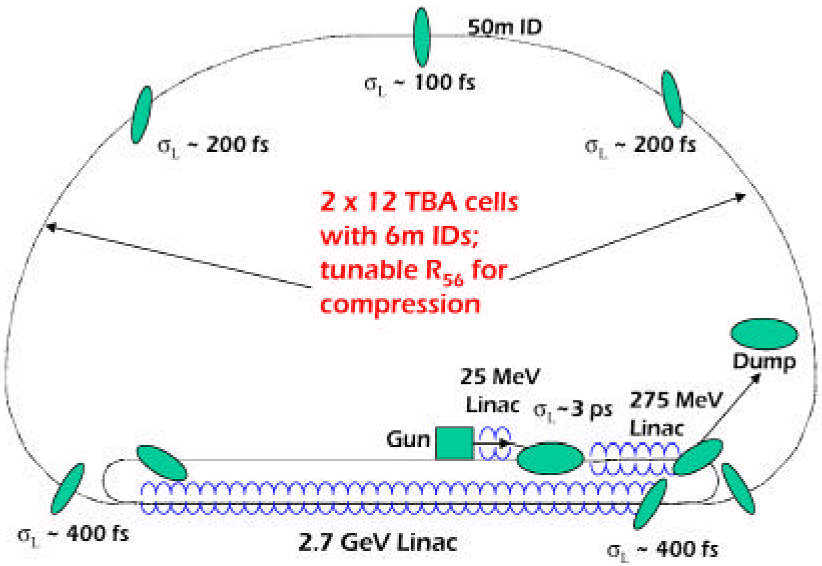
Prototype

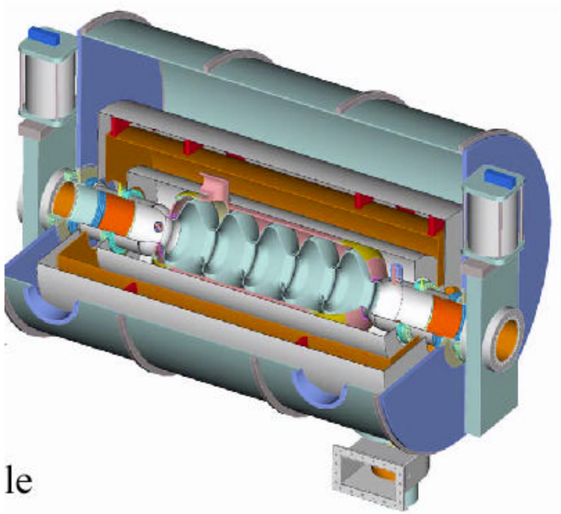




PERL

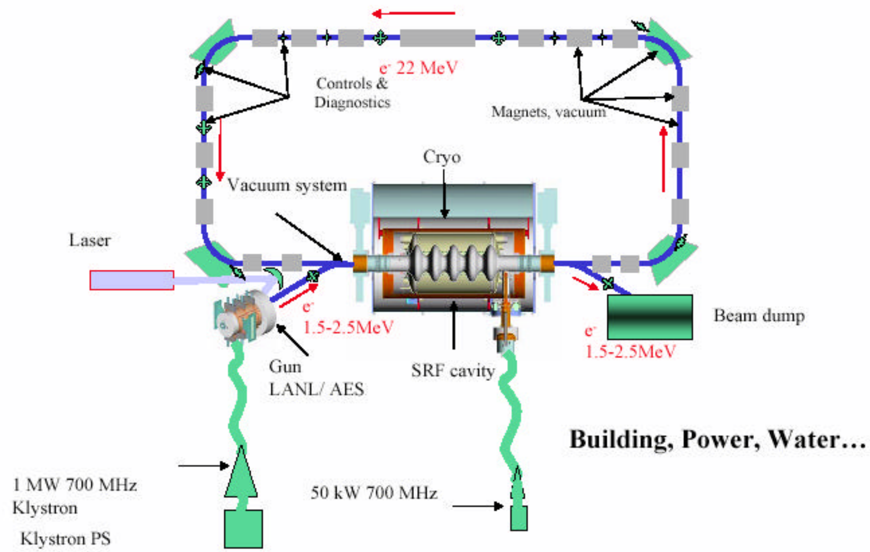
BROOKHAVEN NATIONAL LABORATORY



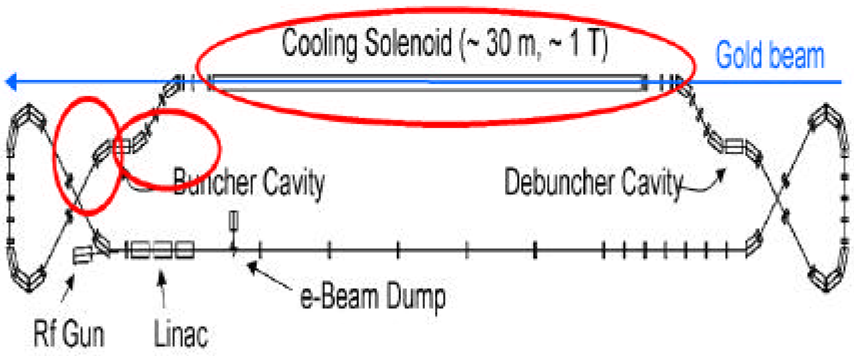


le

A Complete ERL for R&D

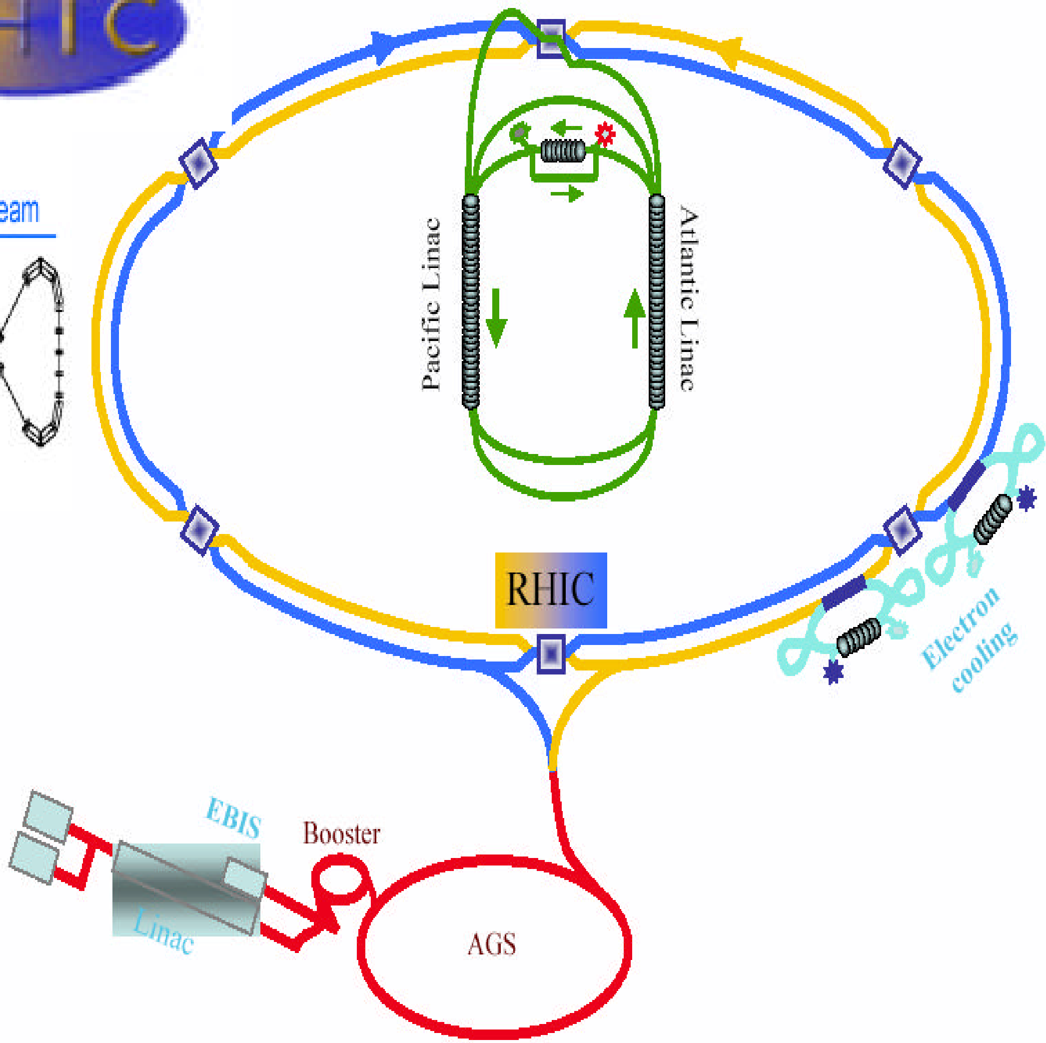


Prototype

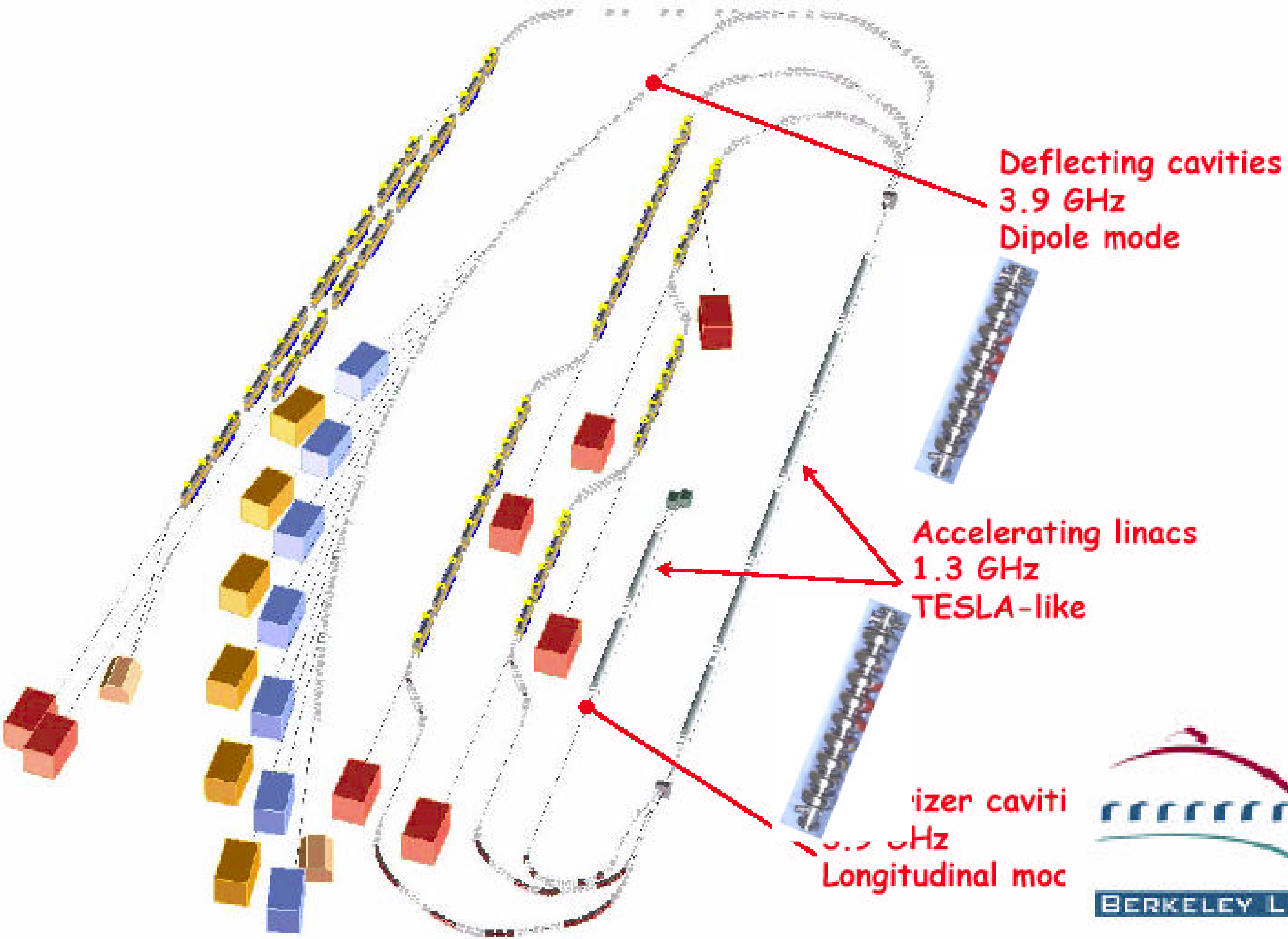


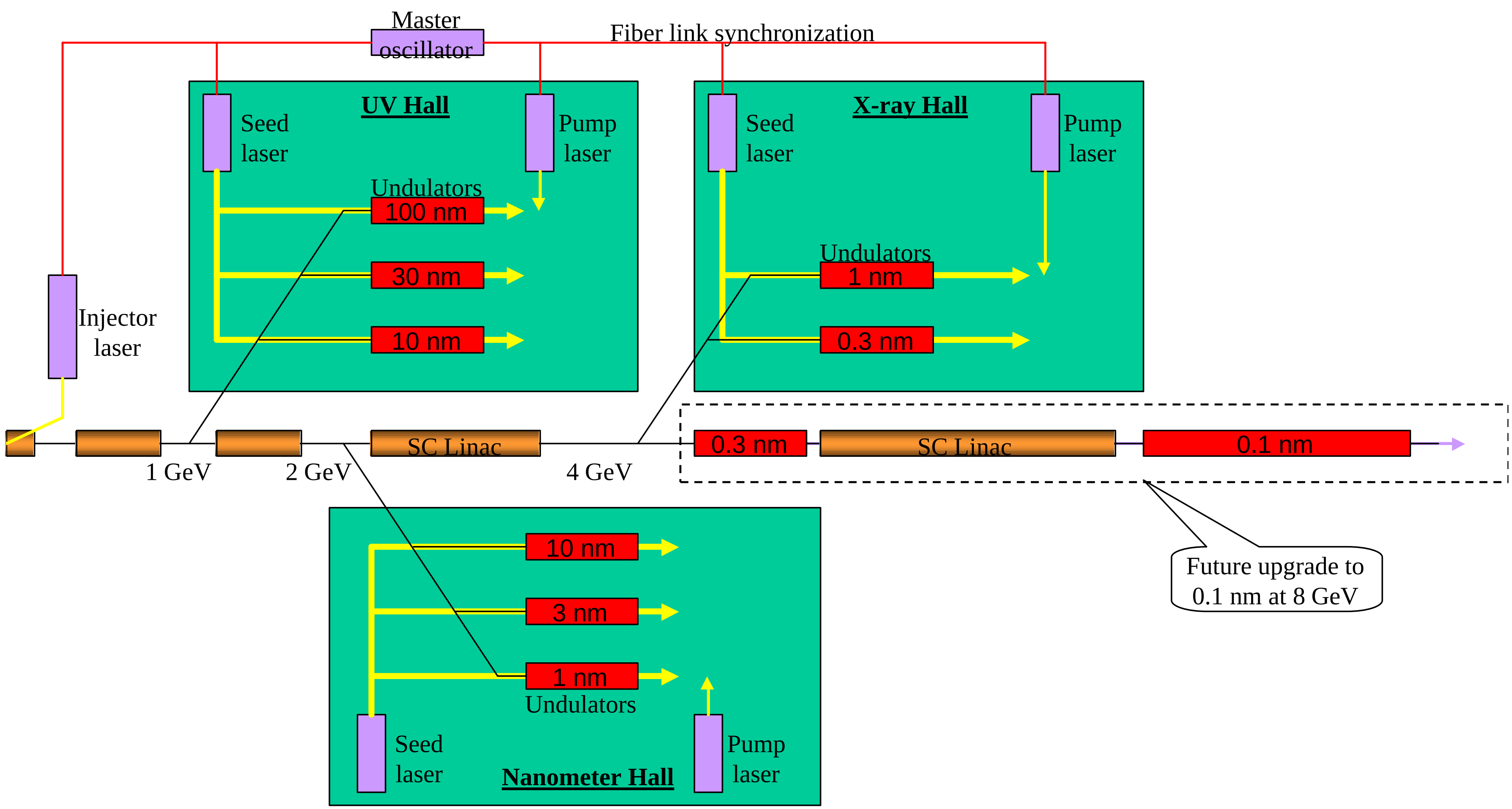
ERL for cooling
RHIC beam

e-RHIC

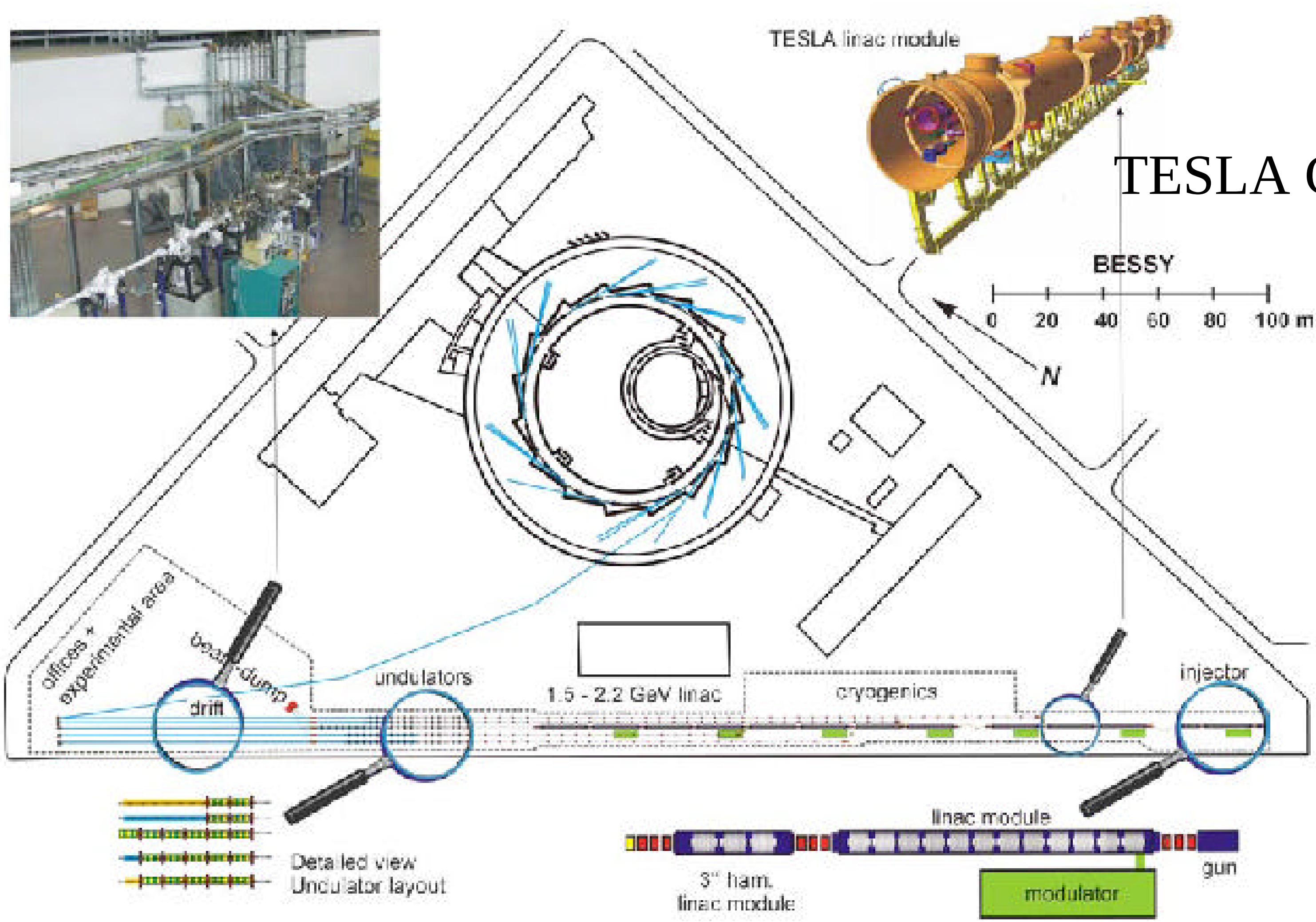


LUX Linac-Based UltraFast Xray Facility



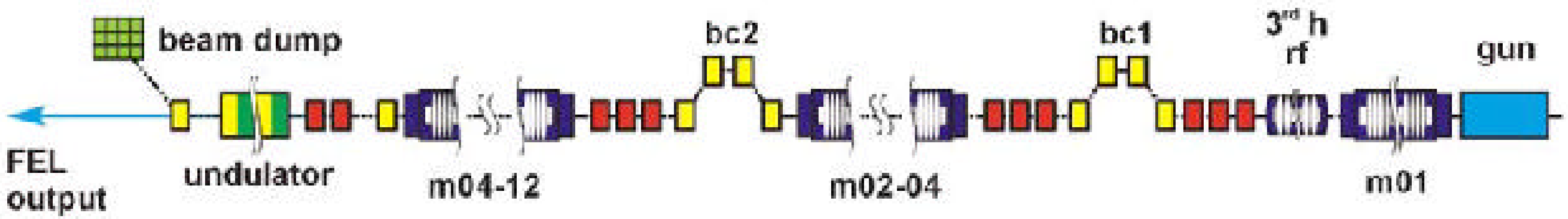

Master oscillator
Fiber link synchronization
UV Hall
Seed laser
Pump laser
Undulators
100 nm
30 nm
10 nm
X-ray Hall
Seed laser
Pump laser
Undulators
1 nm
0.3 nm
Injector laser
1 GeV
2 GeV
SC Linac
4 GeV
0.3 nm
SC Linac
0.1 nm
Future upgrade to 0.1 nm at 8 GeV
10 nm
3 nm
1 nm
Undulators
Seed laser
Pump laser
Nanometer Hall

1 - 4 GeV



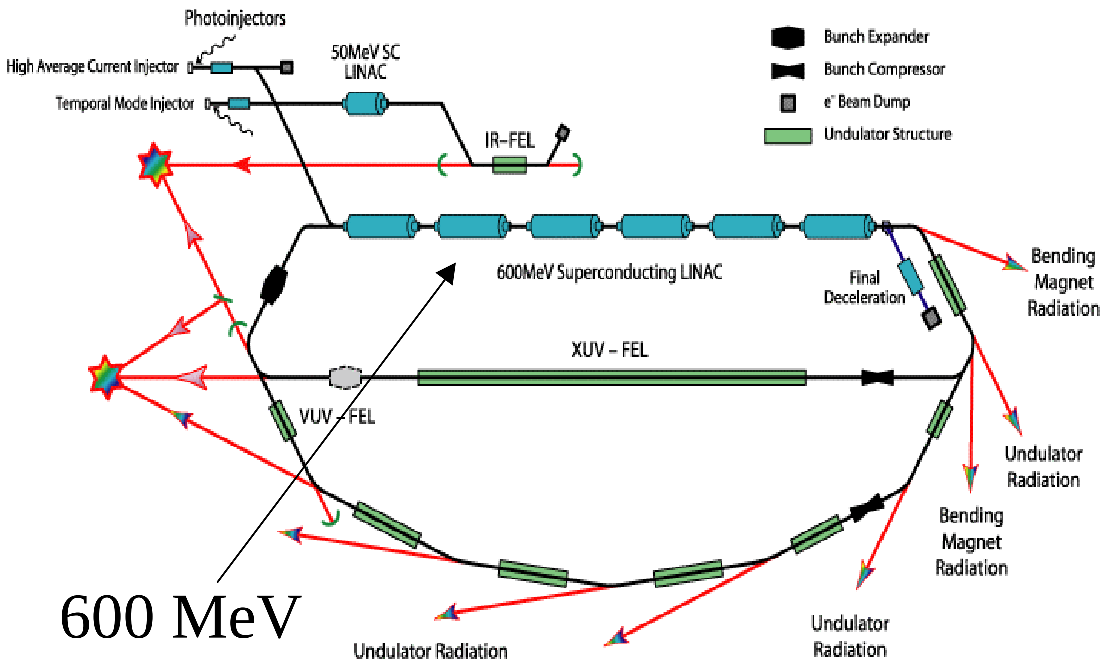
TESLA Cryomodule

BESSY

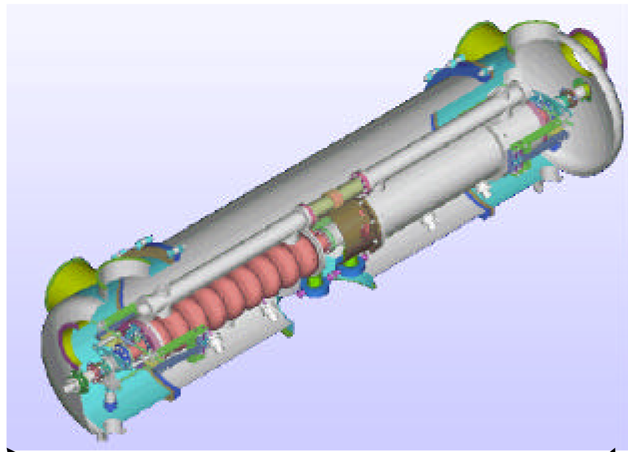


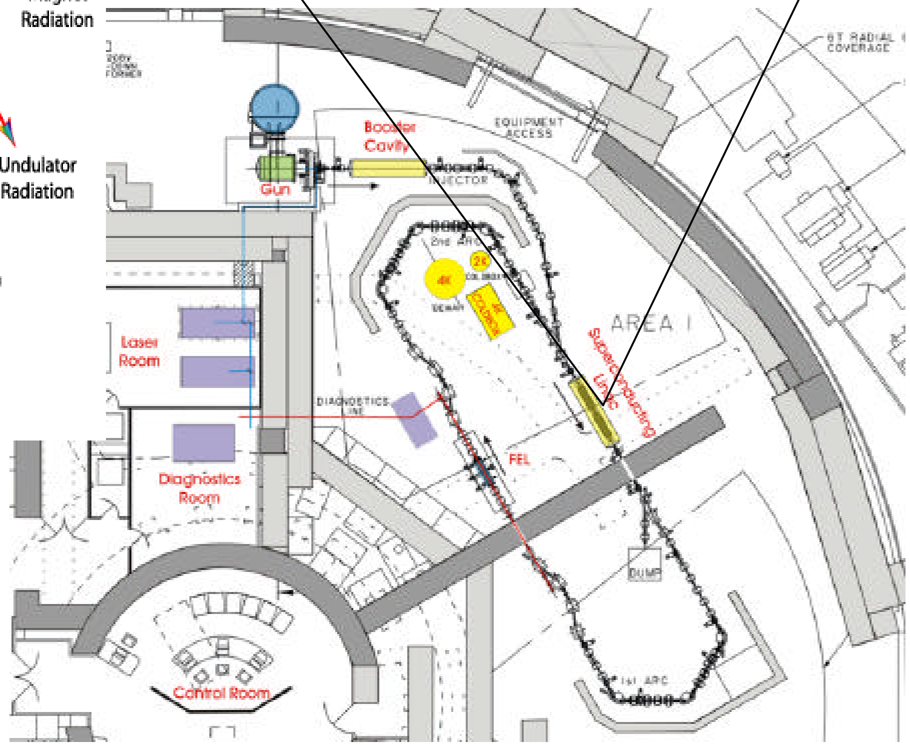
ASTeC
accelerator science and technology centre

4GLS
DARESBURY



600 MeV

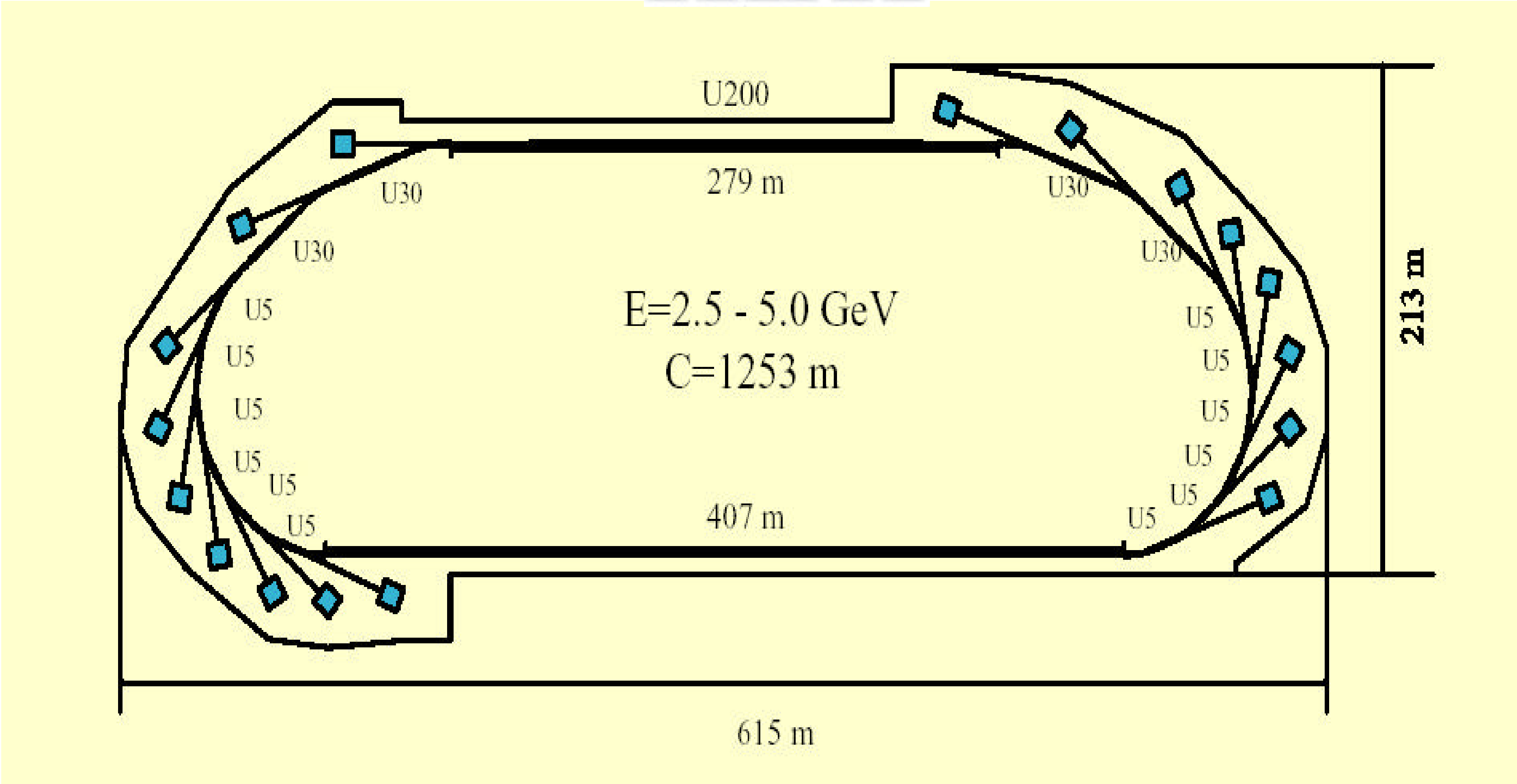




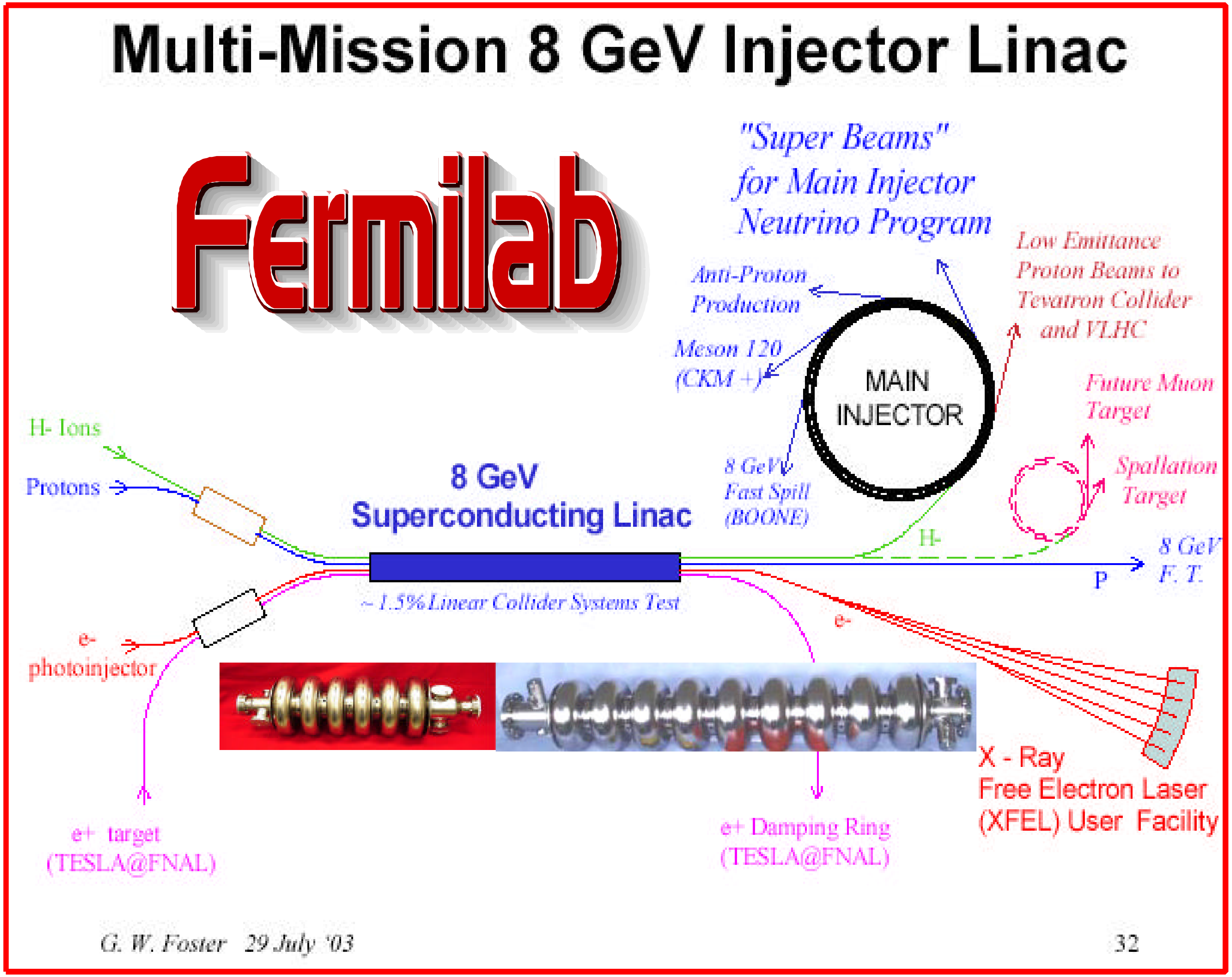
Prototype 30 MeV

～宇宙と物質の
起源と構造を探る～

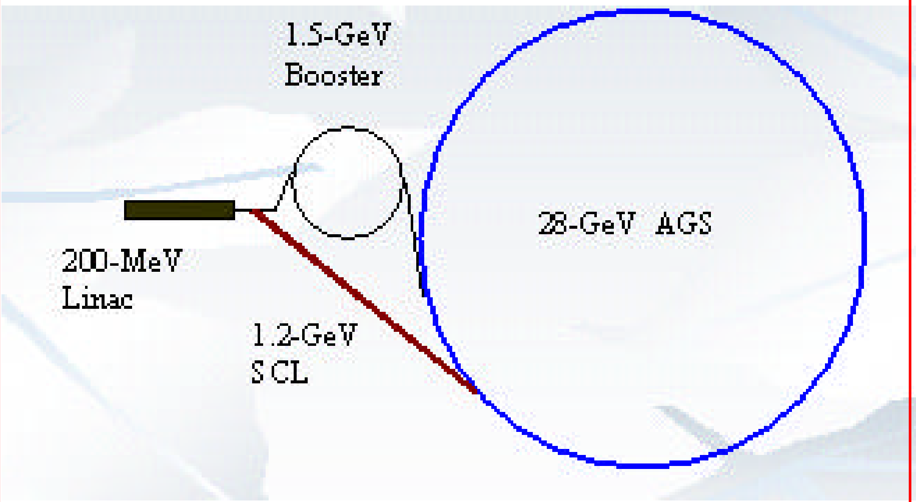
KEK



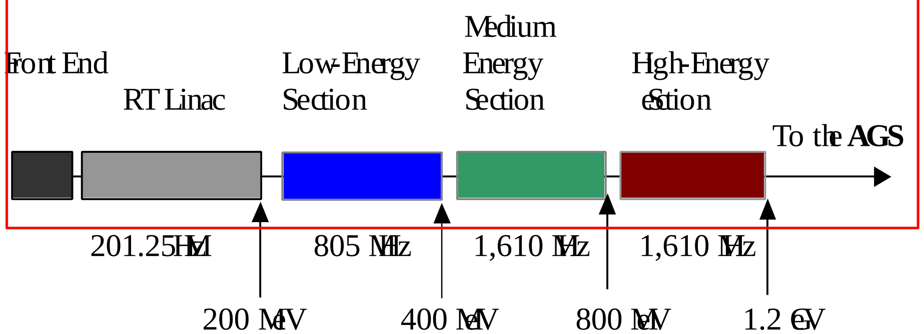
Multi-Mission High Intensity Proton Linacs

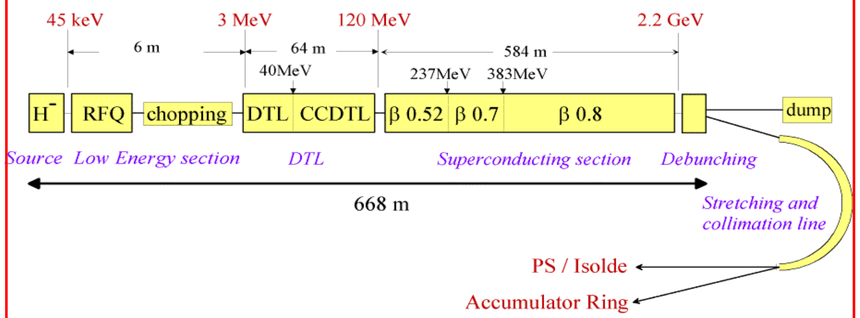


Multi-Mission High Intensity Proton Linacs

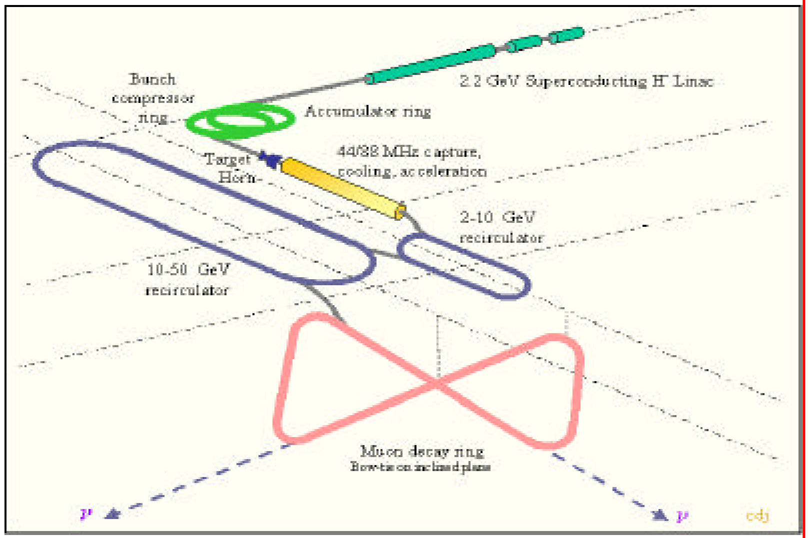


BNL





CERN



Major SRF Capabilites and Facilities Exist World-Wide for Cavity and Cryomodule Design, Development, Production, Assembly, Testing

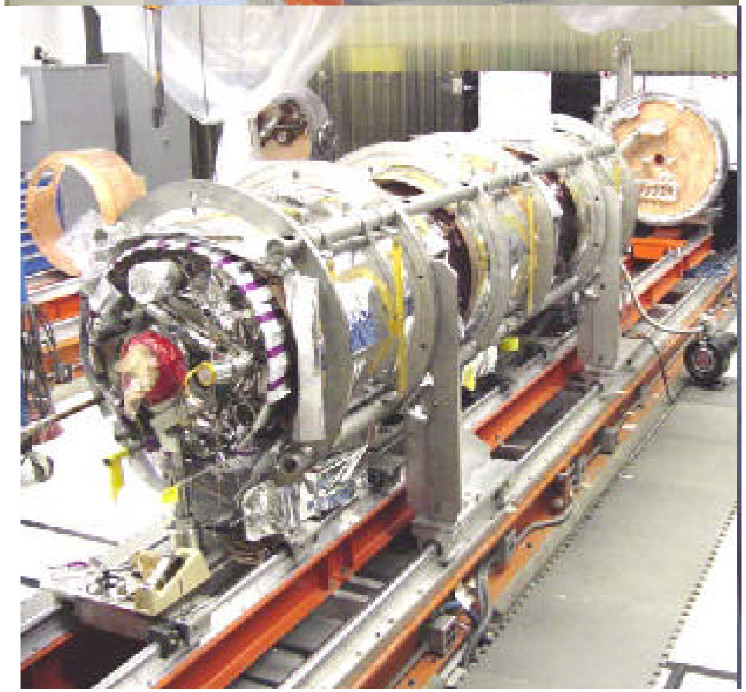
- USA
  - JLAB, Cornell, Fermilab, Argonne, MSU, LANL
- Europe
  - DESY, SACLAY, INFN, CERN
- Japan
  - KEK

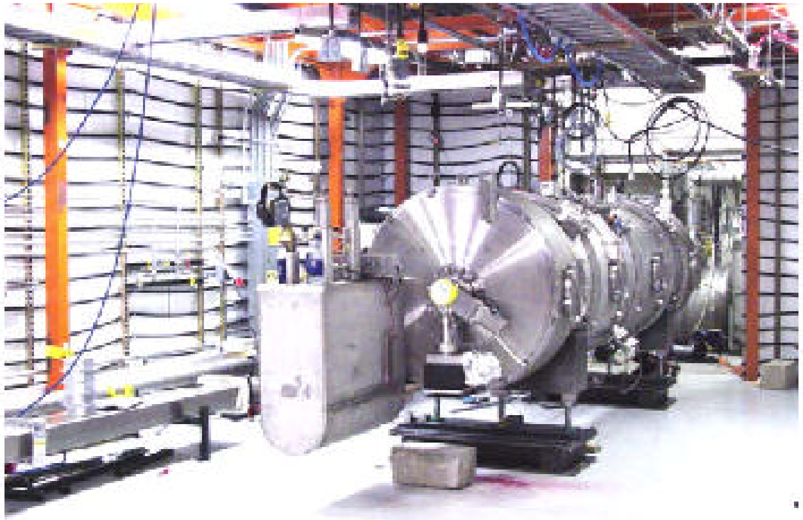
JLAB

Cavity Vertical Test Areas

Cornell
Cavity
Test Pits

Jlab - Cryomodule Assembly and Test Areas





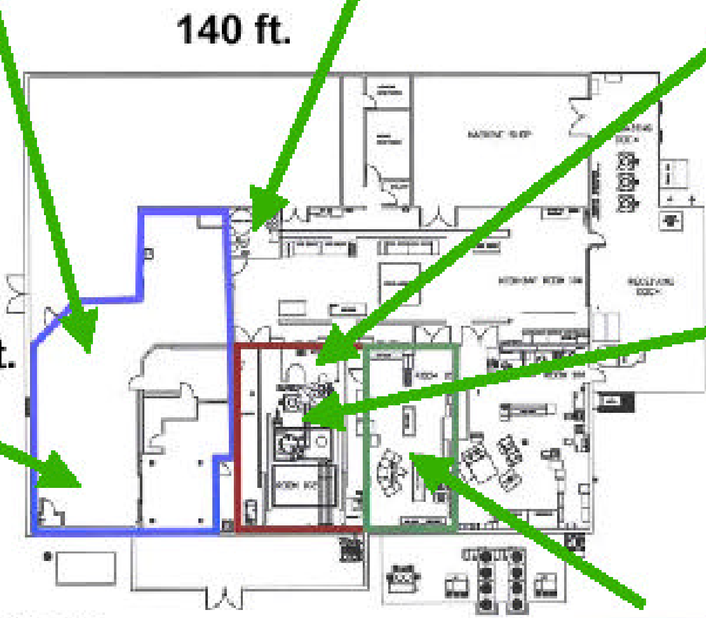
Cryomodule Test Facility (CMTF)

Los Alamos Nat Lab - SRF Facilities

2. Assembly with flanges, couplers, valves, etc. in a 2600 ft² Clean room

1. Ultra-pure water is used for HPR and assembly.

3. Set on the cryostat insert

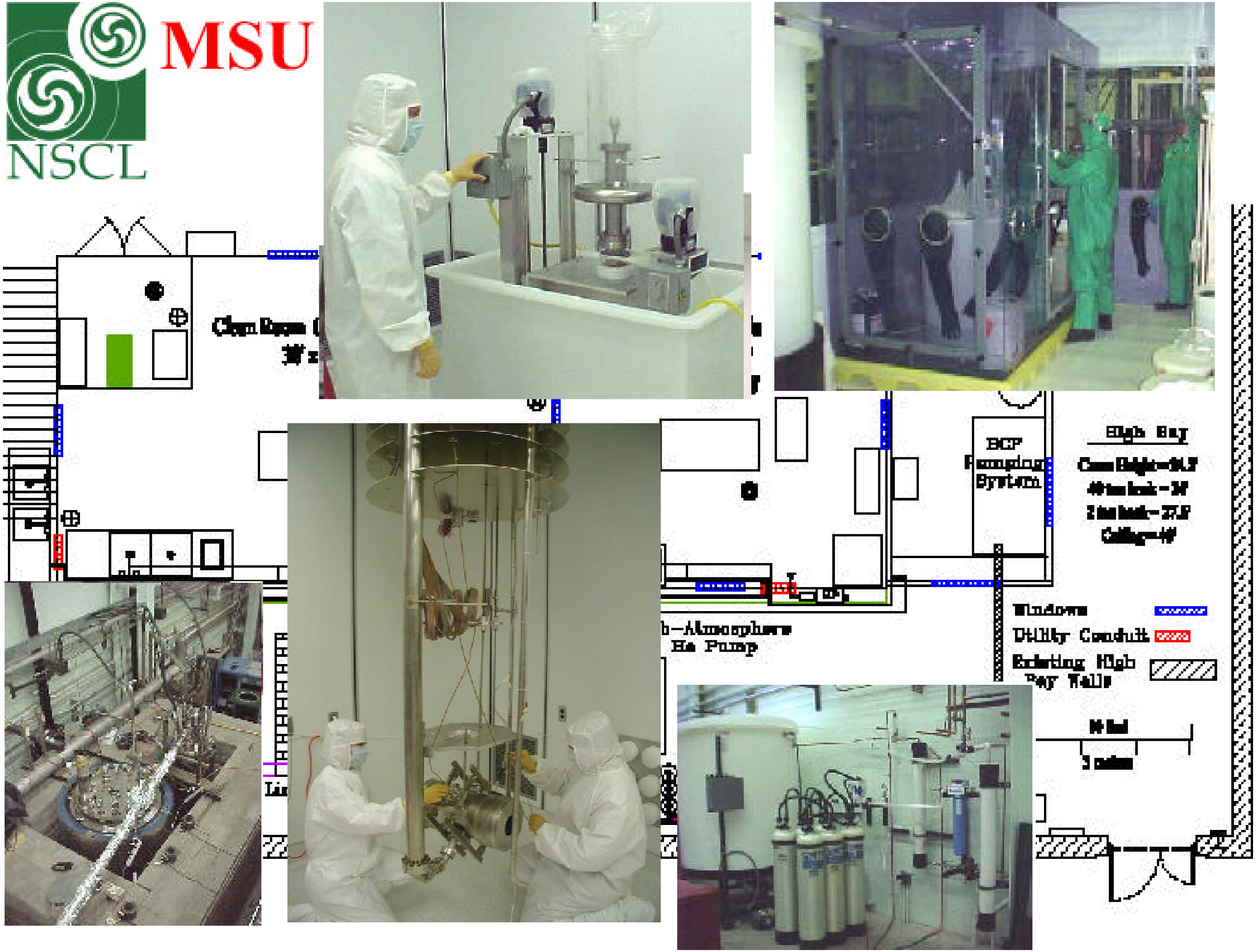


4. Inserted in a 38" cryostat with radiation shield

High-pressure rinsed in a clean room.

Control, tuning

MSU
NSCL


High Bay
Windows
Utility Conduit
Existing High Bay Walls
He Pump

Conclusions

- Steady growth world-wide of SC accelerators
- Substantial operating experience and a robust technology, pushing beyond design
- Continuous increase in performance has launched new projects
- Major facilities exist world-wide at more than 10 institutes to help launch the cold linear collider
- TESLA technology will be important to advance basic science:
  - particle physics, nuclear physics, materials science, life sciences